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GRAND TRUNK RAILWAY SYSTEM

(S.M.P. 73) D

CLASS INSTRUCTION BOOK

IN

MECHANICAL DRAWING

FOR

SHOP APPRENTICES
MOTIVE POWER AND CAR DEPARTMENTS

OFFICE OF GENERAL SUPERINTENDENT
MOTIVE POWER AND CAR DEPARTMENTS
MONTREAL

JANUARY, 1920

PREFACE

The object of the lessons outlined in this course is twofold, namely, to train one to thoroughly understand the principles of projection used in all mechanical drawings, and to give the training necessary to make such a drawing.

Incidentally, the experience gained in doing so will enable the apprentice to be able to read a working drawing when placed before him.

The degree of success attained will be measured by the amount of thought and practice given to the subject, and the time is only lost when a student attempts work of this nature without having his mind on the subject in hand.

The course has been made as practical as possible. Sufficient problems have been given in Plane Geometry to enable the student to lay out most of the work which arises in shop practice, and serve at the same time to train the beginner in the proper use of the drawing boards, set squares, and instruments.

The problems given in Geometrical Projections fully illustrate the requirements of projection necessary to the proper making of a mechanical drawing, provided the apprentice applies close study and diligent practice.

INTRODUCTION

Everyone engaged in mechanical work should understand the rudiments of mechanical drawing so that he can "read" drawings and sketches without difficulty. Drawing is a universal language, and the mechanic who does not understand the first principles of making drawings encounters many difficulties. A sketch tells much that cannot be described in words. It is almost as impossible for a man to succeed, if he does not understand mechanical drawing, as it would be if he could not read nor write.

A mechanic does not need to become a full-fledged draughtsman in order to read and fully understand a drawing, but nevertheless he must study the principles of drawing if he is to become familiar with reading blueprints. Along with the study of these principles and rules there must go considerable practice in actual drawing. This is doubly useful to a mechanic, for there will be numerous cases when he will wish to "sketch" out a job quickly, say perhaps when a simple article is needed in a hurry from the blacksmith's forge, and at such a time his knowledge of drawing will prove very useful and serve him well. Most mechanics from time to time have ideas which they consider improvements over the usual methods, and frequently a drawing is needed to present the idea clearly. It often happens that a mechanic is sent to inspect a piece of machinery that has given out or been damaged; in making a report on a matter such as this it goes without saying that a sketch will be needed on which to show the location of the flaw or other damage.

After getting an insight into practical drawing a great many boys develop a liking for it that leads them into making it a hobby for their spare time, and, such being the case, it is certainly time well and profitably spent.

TO THE APPRENTICE

The course in drawing presented by this book has been prepared so that by carefully working out all the problems and doing the exercises in the order given, you will be led to a stage where you will understand any blueprints coming to you in the shop.

In addition to this you will be able to make good "free-hand sketches" of machine parts, and from these prepare neat and accurate line drawings by the use of the drawing instruments.

The course contains many problems in Plane Geometry inserted where they are needed to explain the drawing. These problems will be found useful to you in the shop, for they are used extensively in all cases of "laying-out" and performing such operations as squaring up plates, etc.

You must cultivate ability to make accurate measurements, and the practice secured in the classroom will be of great use to you in your practical shop work.

Mechanical drawings, as the name indicates, are made mechanically, that is, with instruments, and are thus distinguished from drawings made freehand.

The instruments included in a simple set vary greatly, but usually a set contains a pencil compass, a pair of dividers, a ruling pen and a compass pen. These are the instruments actually needed, but sometimes more elaborate sets are used for making special drawings.

Examine your equipment provided by the Company and see that none of the parts are missing; it should consist of the following:

- Drawing board.
- T-square.
- 45-degree triangle.
- 30-, 60-degree triangle.

Rule

Before starting to draw you will need a drawing pencil (2-H); $\frac{1}{2}$ doz. small thumbtacks; a rubber eraser; a sheet of paper; and a sketching book.

In using the T-square it is placed on the board with the head against the left-hand side. It can be made to slide up and down, keeping the head in contact with the edge of the board, and the blade can be used as a ruler for drawing horizontal lines. When a number of lines have been drawn in this manner they will be parallel to each other. The word horizontal is given to all lines running across the paper from side to side, such as the lines AB in Fig. No. 1.

When placing a sheet of drawing paper on the drawing board make the top edge exactly horizontal, using the blade of the T-square to guide you, then fasten it by means of four thumbtacks as shown in Fig. 1. When ruling horizontal lines with the T-square use only the upper edge of the blade as a ruler.

Exercise 1. Place a small sheet of paper about 12in. by 18in. on the board and practise drawing horizontal lines. Use the T-square as instructed and place the lines exactly $\frac{1}{4}$in. apart and 10in. long, leaving an even clear space or border around the sheet. Space off the $\frac{1}{4}$in. distances, first using the rule.

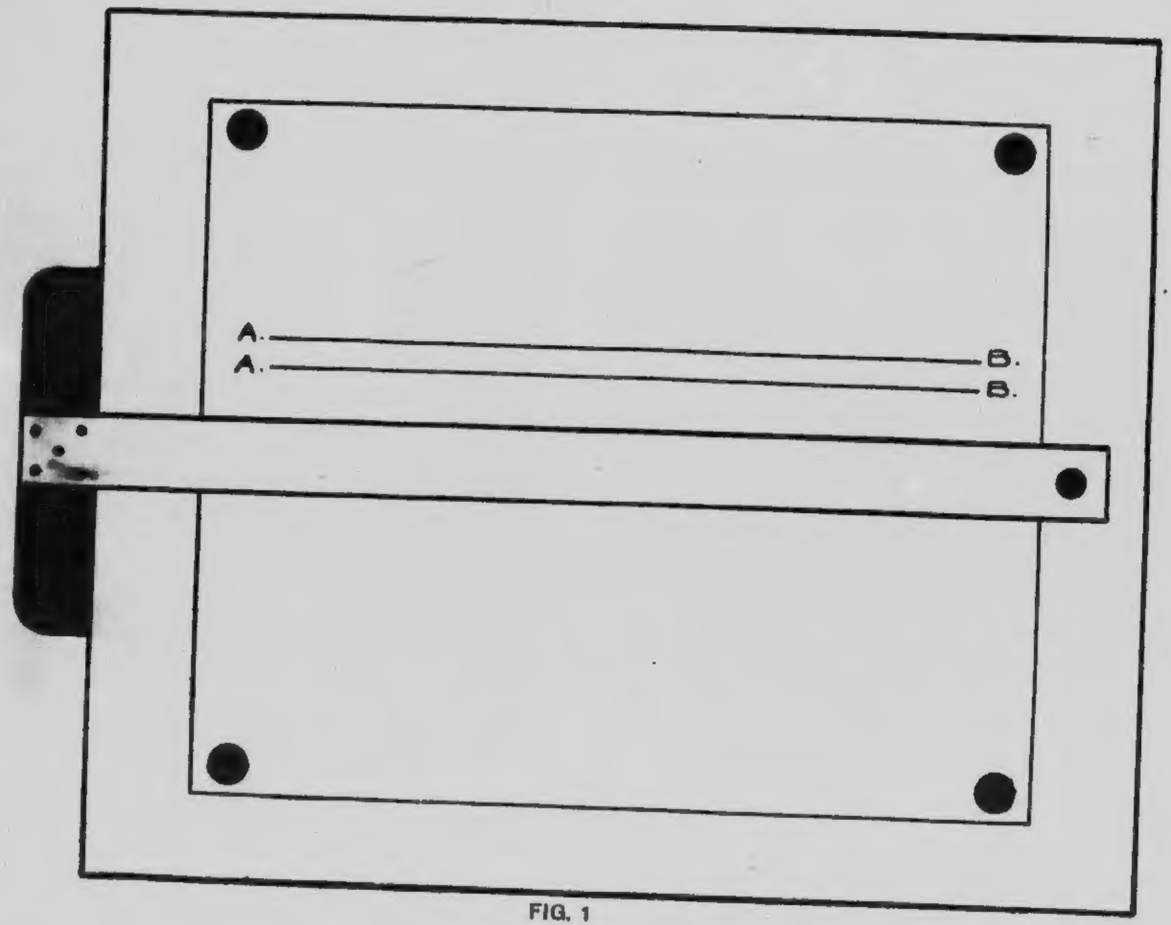


FIG. 1

In this lesson the use of the "triangles" is introduced. There are two of these, one being called the 45-degree and the other the 30-, 60-degree triangle. (The word degree is generally abbreviated; a small circle thus ° always signifies degrees.) In order to know them apart, remember that the 45° triangle has two of its sides equal in length, while in the 30°, 60° triangle no two sides are the same length.

Place the 45° triangle as shown in Fig. 2 in contact with the upper edge of the T-square, keeping the head of the T-square snugly up to the edge of the drawing board. The triangles can be moved along the T-square, and if desired, the vertical edge may be used for ruling vertical lines. Always be sure that the triangle rests squarely on the T-square, and that the head of the T-square is up against the edge of the board. For drawing vertical lines, as indicated in Fig. 2, either of the two triangles may be used.

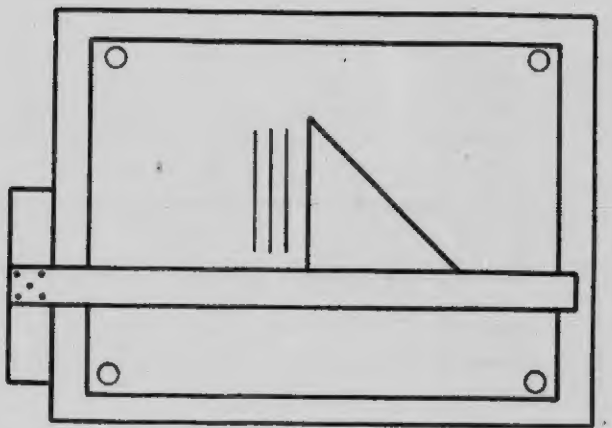


FIG. 2

Study Fig. 3 and Fig. 4 and see how lines can be drawn at an angle, using the triangles. In Fig. 3 the lines AB and CD are drawn with the T-square, and the lines CA and DB with those parallel to them are drawn with the 45° triangle. These last-named lines will then be at 45° to the lines AB and CD.

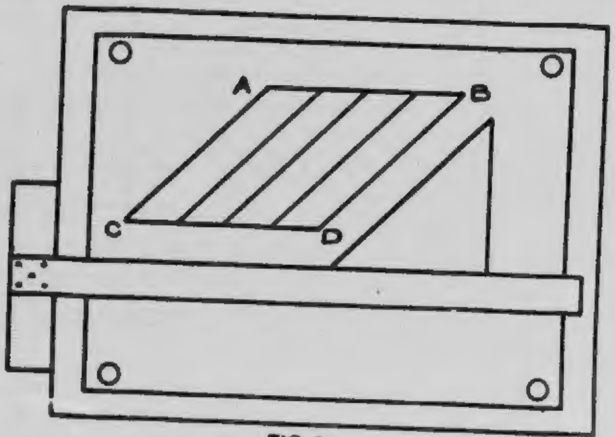


FIG. 3

Fig. 4 shows at (a) how to draw lines at an angle of 60° to a horizontal line, and at (b) the same triangle is used to draw lines at 30° to the horizontal. You will see now how the triangles get their names—the 45° triangle and the 30°, 60° triangle.

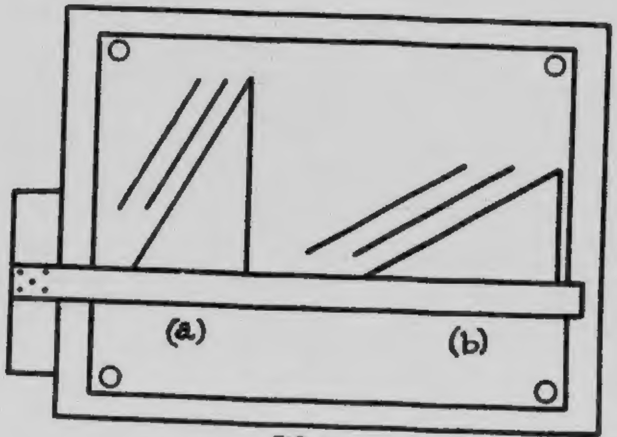


FIG. 4

DRAWING TO MEASUREMENT

We will use the T-square, the rule, the 45° triangle and the pencil for this lesson, and the special purpose is to become familiar with the rule.

When laying off measurements for the following figures, great care must be used to get the sizes exact, and the student should not be satisfied with any work but the very best he can produce.

Lay out an 8in. square, that is, a figure whose four sides are each 8in. long. A good plan to follow is to draw the bottom line of the square and one side lightly at first. Use your rule and measure off these two lines exactly, then complete the square with your T-square and triangle. Afterwards go over the outline exactly and make it heavier. Also lay out a 4in. and a 2in. square on the same sheet of paper.

Draw a light line diagonally across each square, that is, from one corner to the opposite corner in each square, using the 45° triangle for this purpose. On this diagonal line lay off points or measurements as follows: For the 8in. square these points should be $\frac{1}{4}$in. apart, starting at one corner and letting the last measurement come where it will. On the 4in. square make the points $\frac{3}{16}$in. apart, and on the 2in. square $\frac{1}{8}$in. between points.

Now, using the T-square and 45° triangle, with the triangle as the ruling edge, draw light lines through these points in each square; these lines will be at right angles to the diagonal line. (A right angle is an angle of 90°, as seen in the corner of a square; find the right angle on each of your triangles.)

When drawing in these lines care must be taken to see that they cut the centre of the point, and the finished result should be three figures similar to that shown in Fig. 5.

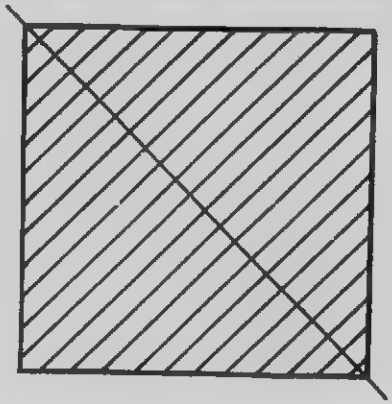


FIG. 5

One thing we wish to emphasize is that the student should study the instruction sheets of each lesson very carefully; he should try to learn the purpose of each lesson and its important points before attempting to make the drawing.

LETTERING

The average student does not fully appreciate the value of being able to letter well, and while he is seldom pleased with his lettering, he usually does not like to devote the necessary time to practice. A great many apprentices reach the point where they are able to make a neat, workmanlike drawing, the appearance of which they will spoil when they letter and dimension it.

The greatest aid for lettering is to use two **light** lines separated exactly the amount of the desired height of the letter. In measuring off this distance use your dividers, for it is important to get the distance **exact.** Print with a 1-H pencil.

In the illustration you will find the standard letter and figure shapes, and these must be studied and copied until you are able to produce these standard shapes from memory. In making these letters have only one thing in mind, that is, to keep strictly to this standard upright form of letter. Make all the letters in a work the same height, using the guide lines as they are intended.

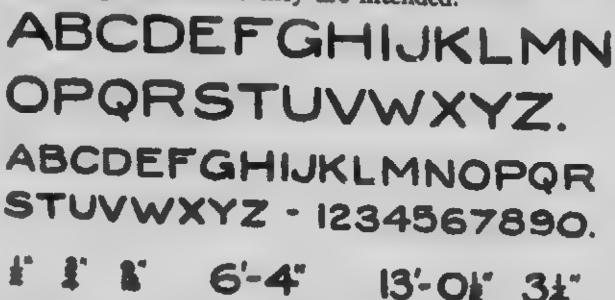


FIG. 6

Frequent practice is necessary, for that is the only way to become a neat letterer.

All notes and dimensions will read from bottom or right side of drawing, according to location of dimension line.

For the present we will only use two different sizes of printing. Figures and notes will be ⅛in. in height and width, and some titles will be $\frac{3}{16}$in. in height and ⅛in. wide. The ⅛in. style will be most used.

Pay particular attention to the spacing of the letters in a word to get a neat, uniform appearance, also leaving a uniform space between words.

In placing dimensions, one short stroke placed above a figure and to the right denotes "feet," and two short strokes denotes "inches." When the size reads feet and inches place a hyphen between the two terms; thus, 6'-4½" reads six feet, four and one-half inches.

All fractions shall have the division line made horizontal as shown thus—¾, and should be $\frac{3}{16}$" in height.

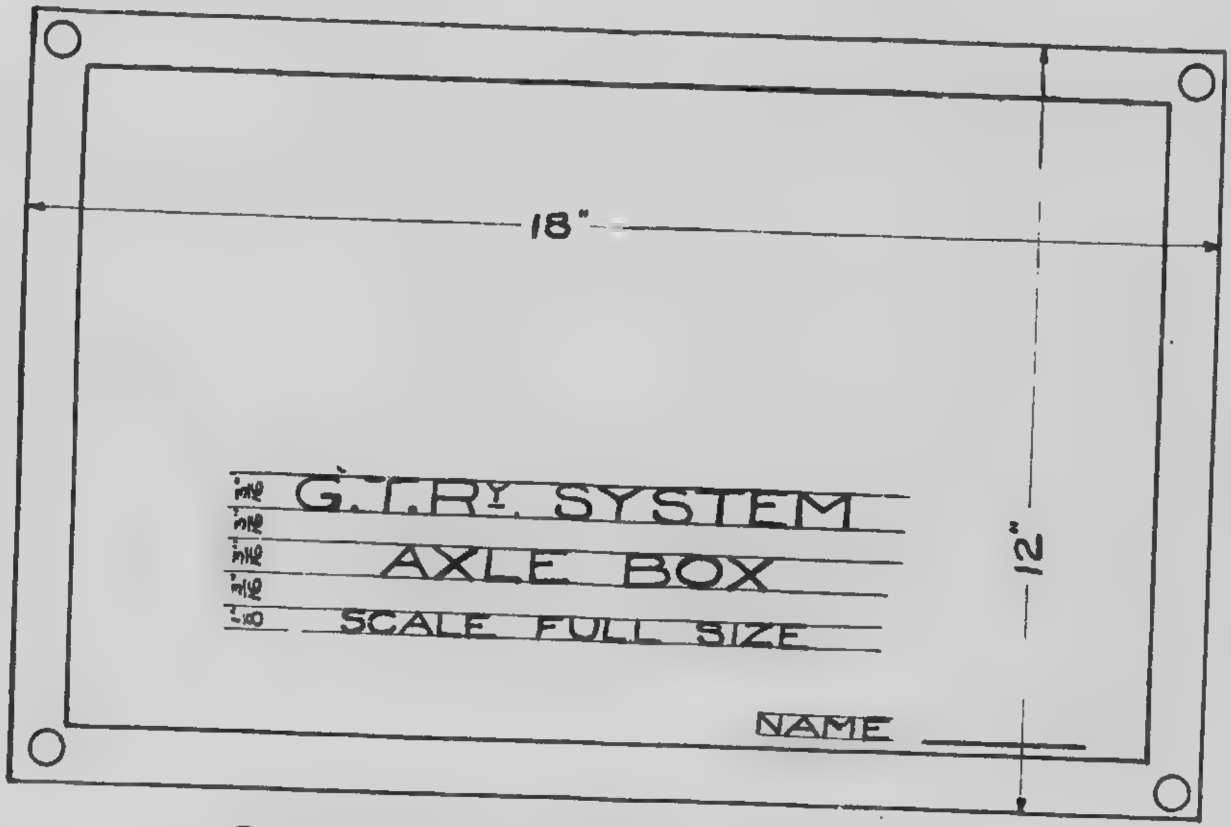
In all the lessons that follow it is desired that the student do all necessary printing, keeping strictly to the standard presented in this lesson.

Exercise 1. After a preliminary practice to get the shapes in your mind, make two neat pencil copies of the illustration.

Pointers

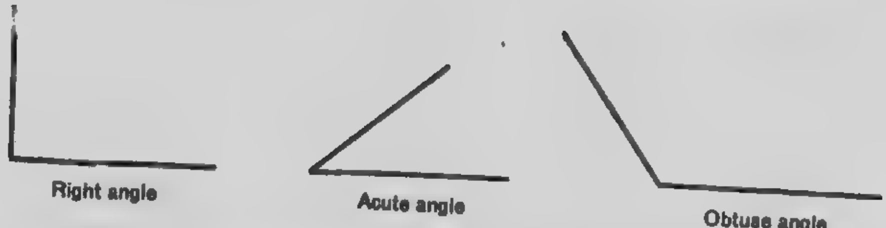
Try to make each letter better than before, keeping the ideal letter in mind to copy from, frequently looking at the letters shown in Fig. 6 to get correct shape. Do not press on your pencil too hard, and do not go over the letters. Cultivate a decisive, straightforward manner in lettering, for this is what gives a good general appearance to your printing.

Do not have your pencil too sharp, or the printing will lack body.



STANDARD DRAWING SHEET.
SHOWING LAYOUT OF TITLE

FIG. 7



ANGLES

An angle is the amount that one line inclines toward another line. Fig. 7 shows three kinds of angles, and it will be noticed that length of the lines have no influence on the size of the angle, for the size of the angle depends wholly on the amount of their inclination to each other. Like all other things requiring measurement, angles have a standard unit by which they are measured; it is known as a degree, and there are 360° in a complete circle or revolution.

An angle containing 90° is a quarter of a circle and is known as a right angle. Any angle **smaller** than a right angle is an **acute** angle, and if **greater** it is called an **obtuse** angle.

PLANE FIGURES

A plane figure is any part of a flat surface. It is completely bounded by a line or lines, and here we will only consider a few of the simple figures.

Previously we mentioned the circle, which is one kind of plane figure.

If the figure is bounded by straight lines only, it is called a polygon, and polygons are subdivided into many groups of figures depending on the number of sides.

In order to give you the proper understanding of plane figures we will base our descriptions on the polygon, and you must memorize a definition for it so that you will be able to grasp the proper meaning of what a polygon is. **All plane figures bounded by straight lines are polygons.**

A polygon can be either "regular" or "irregular," being called regular when all the sides are equal and all contained angles equal.

In each class of polygons there is one regular form and an infinite number of irregular forms. The first class of polygon is the triangle, and the next class the quadrilateral. These two classes are the most important to us, for they are so commonly met with. Each class will be studied separately.

Exercise 1.

(a) Give a definition for an angle.

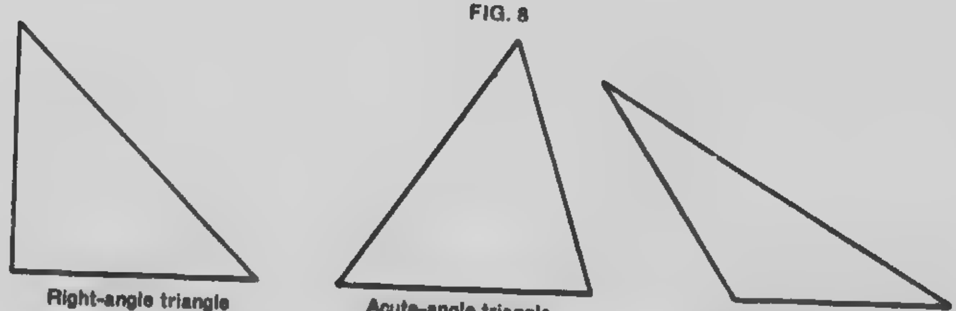
(b) Give a definition for a degree.

(c) Name three general classes of angles.

(d) What is a plane figure ?

(e) What is a polygon ?

FIG. 8



Right-angle triangle

Acute-angle triangle

Obtuse-angle triangle

TRIANGLES

A triangle is a three-sided polygon. Having three sides it follows that it will also have three angles, hence its name—triangle—"tri" meaning three. Fig. 8 shows three general classes of triangles, the names being found under the figures.

The right-angled triangle has one angle a right angle. The side opposite the right angle is called the hypothenuse.

In an acute-angled triangle all the angles are acute.

An obtuse-angled triangle has one angle obtuse.

On preceding page it was learned that each class of polygon had one "regular" form. Among triangles this form is known as the equilateral triangle—see Fig. 9.

Notice that all the sides are equal and therefore all three angles are equal. There is a law concerning triangles it will be well to remember, that, if all three angles are added together you will get 180°. In other words, the total of all the angles of any triangle will equal two right angles, or 180°.

In the case of the equilateral triangle it will be evident that each angle is 60°. Prove this to yourself by reading the above paragraph over again.

FIG. 9

FIG. 10

Isosceles triangle — Scalene triangle

Fig. 10 shows two classes of triangles that are often referred to, and it will be well to know what their names signify.

The isosceles triangle is one having two of its sides equal; no notice is taken of what length the third side has. This form of triangle, since it has two sides equal, must also have at least two angles equal.

The scalene triangle is one in which no two sides or angles are equal to one another.

Exercise 1.

(a) Define a triangle.

(b) Define an equilateral triangle.

(c) Define a right-angled triangle.

(d) Define an isosceles triangle.

(e) Can an acute-angled triangle be isosceles ?

(f) Can a scalene triangle be a right-angled triangle ?

(g) Can an isosceles triangle be a right-angled triangle ?

(h) What is the sum of the angles in any triangle ?

(i) If you know two angles in a triangle how could you figure out the third angle ?

(j) Would it be right to call an equilateral triangle a regular polygon ?

(k) What is the hypothenuse of a right-angled triangle ?

QUADRILATERALS

A quadrilateral is a four-sided polygon—in other words, it is a plane figure bounded by four straight lines. A line drawn to join up two opposite corners of a quadrilateral is called a diagonal.

If a quadrilateral has its opposite sides equal, the opposite sides will then be parallel, and the figure will be known as a parallelogram.

Any parallelogram that has 90° angles (90° is a right angle) is called a rectangle.

Any rectangle whose sides are all equal is called a square.

A square may be called a "regular" polygon because all the sides are equal and all the angles are equal.

Whenever two lines are at right angles to each other they are said to be perpendicular to each other.

In reading over the above geometrical statements try and picture in your mind the object that is being described, so that you can make a sketch on paper to show the Instructor that you understand the statement.

From the above you should be able to define in your own words any of the terms if required to do so.

OTHER FORMS OF POLYGONS

FIG. 11

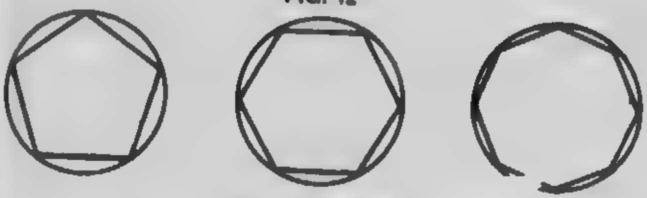
A five-sided polygon is known as a Pentagon.

A six-sided polygon is known as a Hexagon.

An eight-sided polygon is known as an Octagon.

In these three classes we only consider the regular type, or the one that has all sides and all angles equal. Fig. 11 illustrates these forms of polygons.

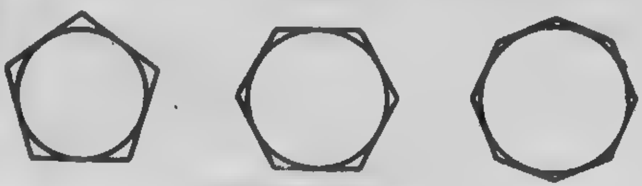
FIG. 12



Inscribed polygons

Any regular polygon may be inscribed in a circle—that is, all the corners will fall on the circumference of the same circle. It is well to remember this, for it is quite often necessary to make use of a circle when drawing these figures. Fig. 12 shows how polygons look when inscribed.

FIG. 13



Circumscribed polygons

Fig. 13 shows the same polygons, only they are circumscribed, that is, placed outside the circle.

SOLIDS

A solid has three dimensions—length, breadth, and thickness. The most common forms occurring in practical geometry and drawing are prisms, cylinders, cones and spheres.

We will only consider the **right prism.** The right prism is a solid of uniform shape throughout, the ends being polygons of the same size and class. To distinguish between the different kinds of prisms, they are named according to the kind of polygon that forms their end.

Thus we have triangular prisms, rectangular prisms, hexagonal prisms, octagonal prisms, etc.

A rectangular prism may have a **square** end, and if all three dimensions are the same, and all faces square, it is called a cube.

A cylinder is a solid having a circular shape throughout, and each end a circle of the same diameter.

A sphere is a solid commonly known as a perfectly round ball.

A cone is a solid converging from a circular base to a point.

A pyramid is a solid converging to a point from any polygon base, thus giving us triangular pyramids, rectangular pyramids, hexagonal pyramids, etc.

LINES USED IN DRAWING

There are several kinds of lines used in drawing, each one of which has a particular purpose, and you must become so familar with them that you can recognize them at a glance when reading a blueprint. More depends on their proper use than any other thing when it comes to making a drawing clear. Fig. 14 shows the lines that are standard in all our work. No two firms or companies use the same lines for the same purpose, but nevertheless it is necessary for us to have a standard and stick to it. In this way our work will be uniform and consistent.

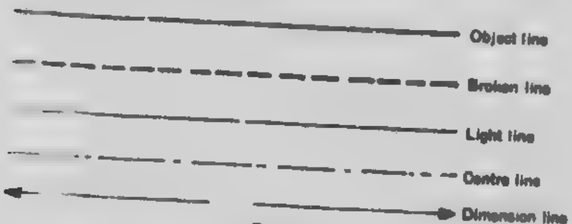


FIG. 14

The "object line" is used to represent all outlines and parts in full view. Draw it distinctly. The "broken line" is the same density as the object line, only broken, being a series of short dashes. It indicates parts that are hidden from direct view, and on that account it is sometimes called an invisible line. We will call it the broken line. The "light line" has many uses. Draw it very lightly. In working up a drawing there is great use made of the "light line" as a construction line, later to be erased or transformed into an object line. The "light line" is used for **projection lines,** although in advanced work these are sometimes omitted, the work being projected directly by the T-square or triangle. **Extension lines** are "light lines" used in connection with **dimension lines.** They are drawn out parallel from certain points on the object and the dimension line placed between them. Fig. 15 has been prepared to illustrate the use of the various kinds of lines commonly used. Study it and notice the duty of each. Make your arrow-heads neatly, keeping them sharp.

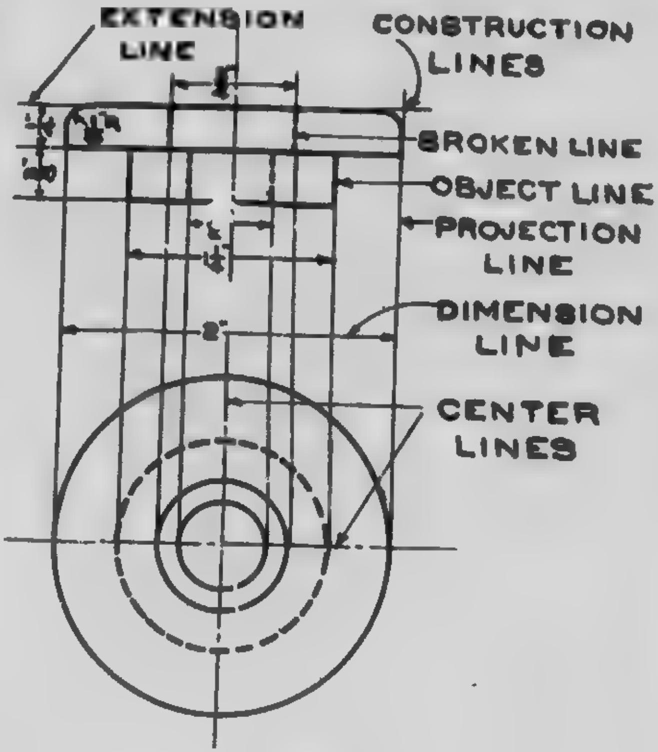


FIG. 15

SKETCHING

Early in this course the subject of freehand sketching is introduced, and you will doubtless become aware that it is no easy task to produce a neat drawing entirely freehand. Before considering more difficult models it will be necessary to spend a little time studying points that will help you in sketching. A knowledge of sketching is exceedingly useful to men of any trade, and you will be given constant practice as you progress through the course.

Method

The method you are advised to follow from now on is the "broken-stroke method." It is called this on account of the fact that the line is not made in one continuous stroke, but in a series of strokes all joined together into one line leaving no open spaces, the elbow and fingers being frequently adjusted to keep the line forming in the desired direction. (Nothing but diligent practice will develop your ability to make freehand drawings.)

The object of using these short strokes is to enable you to correct an error in the direction of the line. The result is that the general direction of the line is straight, even although there may be slight errors at different points along the line.

Pencils

An H or HB pencil, well sharpened, is most satisfactory for sketching. Learn to hold the pencil easily and naturally in a manner very similar to that used in writing.

Do not turn the paper to suit the direction in which the line is to be drawn. Develop freedom of movement of fingers, wrist and arm, and ability to draw lines in any direction with ease.

It is quite difficult to make neat circles freehand, but by putting the following suggestions into practice you should obtain satisfactory results.

Sit upright while drawing, so that you may better get a clear view of your work as a whole. Keep your head well above the work, and you will find that you can direct your pencil better and keep your drawing in proportion. To draw a circle start in at the left-hand side and with short strokes form the upper half. Then, starting at the same point, form the lower half in the same manner.

Exercise 1. Take a sheet of common paper and draw a large rectangle about 12" x 8"; subdivide it into 4" squares. Do this on the drawing board and use the squares. Putting away all tools except your pencil and rubber, sketch four of the squares full of parallel lines about $\frac{1}{16}$" apart. Complete the exercise as suggested in Fig. 16.

Exercise 2. Turning the sheet over, practise drawing freehand circles, ½", 1", 1½" and 2" in diameter. Draw the circles as near as possible to these diameters, without using the rule. Do not hurry these exercises through too quickly, for they are important.

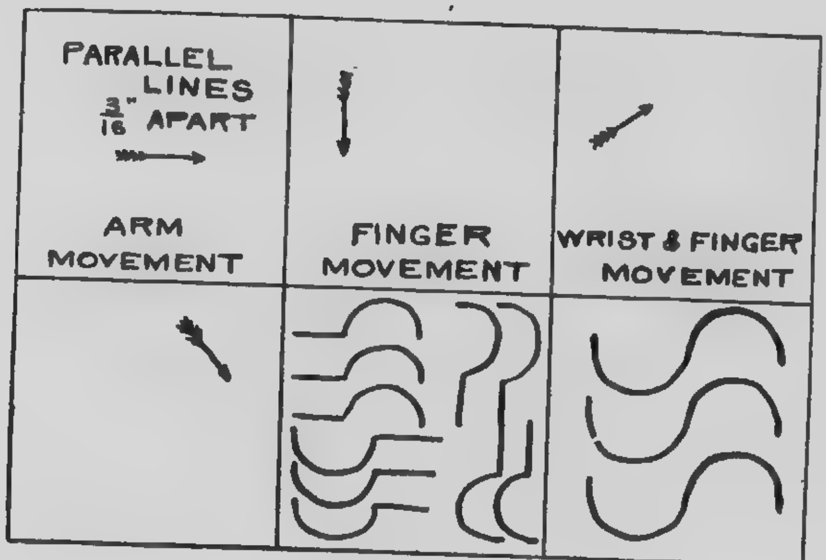

PARALLEL LINES
3/16" APART
ARM MOVEMENT
FINGER MOVEMENT
WRIST & FINGER MOVEMENT

FIG. 16

THE USE OF THE COMPASS

The compass is an instrument used to draw circles and arcs, and to obtain good results it will be necessary to practise carefully and have the points in the best possible condition. The lead should be filed off to a chisel point and the length of the lead adjusted so that the leg of the compass is just a trifle shorter than the leg containing the needle point.

Suppose we are to describe a 2″ circle. (*Note.*—Describe means, in this case, to draw.) Taking the rule in one hand and the opened compass in the other hand, close the compass until the points are exactly 1″ apart on the rule. Having located the centre of the circle by a point on the paper place the needle-point exactly on it, piercing the paper very lightly. Now, holding the compass by the upper end with two fingers and the thumb, begin the circle at the lowest point and turn the compass so that the lead will describe a complete circle on the paper. The aim should be to produce an even and distinct circle with one rotation of the compass, and without pressing too hard. To help obtain these results use a slightly softer lead in the compass than is used in your pencil. Do not slant the compass very much and try not to produce an unsightly hole at the centre point.

Exercise 1. Take a sheet of paper and practise drawing circles of an exact size until you have satisfied the Instructor that you can handle your compass properly. Cultivate the proper methods from the start.

Now that you have learned how to make a circle mechanically it will be well to study some of the terms we use in connection with circles, so that you can properly define them when called upon to do so.

We refer to the line produced by the compass as a circle, but in reality a circle is a plane figure and the line referred to is its boundary. Keeping in mind how you constructed the circle with the compass, you will see that every circle has a "centre" point and that all parts of the boundary line are the same distance from the "centre."

The radius of a circle is the distance from the centre to the boundary, and the diameter is twice the radius or the distance across the circle at its largest part, that is, measured through the centre.

Exercise 2. Draw two circles each $2\frac{1}{4}$″ in diameter. On one draw a line indicating the radius of the circle. On the other draw a line indicating the diameter of the circle. By actual measurement compare these two lines and see that the one is exactly twice as long as the other.

The part of the circle referred to above as the boundary is also called the circumference, often described as the distance around a circle.

An arc of a circle is any portion of the circumference of that circle, and if the arc is placed so as to connect two straight lines it is called a "fillet."

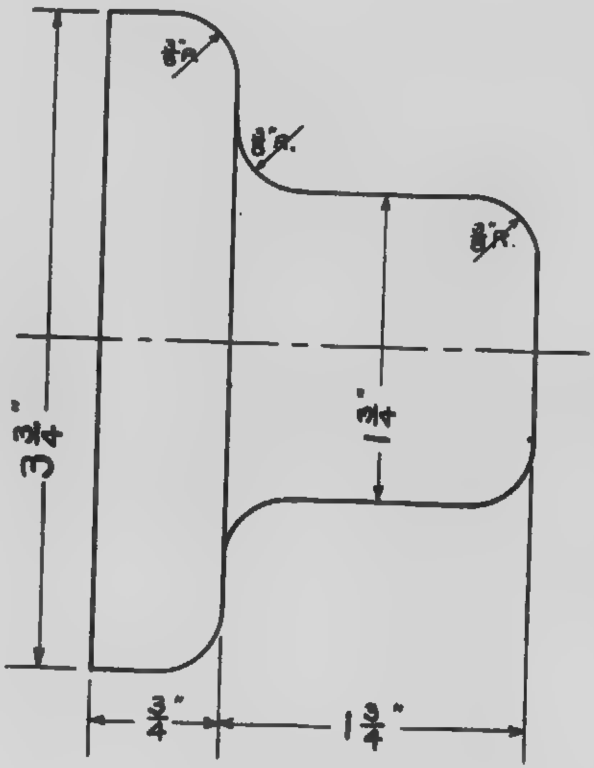


FIG. 17

Fig. 17 gives an illustration of how these arcs are used to connect the straight lines, both for fillets and rounded corners. They are very common in the construction of machinery and castings.

The most practical method of locating the proper centre point for a fillet is by trial. Use the small bow compass and work very lightly until you have located a point that will place the arc exactly where you want it. In cases where fillets are required draw the straight lines faintly at first, then place the fillet distinctly, afterwards going over the straight lines and joining them exactly to the fillets, and making them the same shade or density. Aim to have the finished work so uniform that there is no abrupt difference in the lines drawn with the compass and with the pencil. Here, again, considerable care and practice is required. Further on we will find a method shown for locating the centre of a fillet for a right-angled corner, using a geometrical construction.

It is customary to place a centre line on all views of an object that is round. For example, in Fig. 17 the object shown there is round when viewed from the end; thus the centre line, made of dashes and dots, is drawn through the centre of the view. In drawing end views of this class of objects—in fact, whenever a circular view is drawn—two centre lines are used, the one being at right angles to the other, intersecting at the centre point of the circle.

DEFINITIONS

The following definitions relating to all drawings must be thoroughly understood to ensure progress.

A **Point** has position only.

A **Line** has length but no breadth, and the ends of a line are points.

A **Straight Line** is the shortest distance between two points.

An **Angle** is the inclination of one straight line to another.

A **Right Angle** is made when one straight line standing on another makes the two adjoining angles equal; thus, if the angles ACD and BCD are equal, both of them are right angles.

Parallel Lines are the same distance apart at all points on their length, and would never meet if produced both ways.

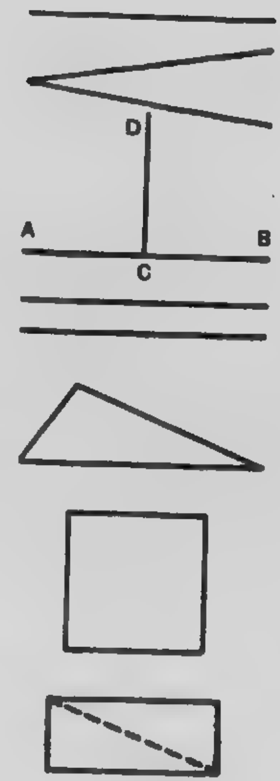
A **Triangle** is a figure enclosed by three straight lines, or sides. The sum of the angles of any triangle is equal to 180 degrees.

Quadrilaterals are figures enclosed by four straight lines, the most common of which are:—

The **Square,** which has all its sides equal, and all its angles are right angles.

The **Rectangle,** which has its opposite sides parallel and equal, and its angles right angles.

A **Diagonal** is a straight line joining two opposite angles of any figure.



DEFINITIONS—(Continued)

A **Circle** is a figure contained by one line called the circumference, and is such that all straight lines drawn from a certain point within the figure to the circumference are equal to one another, and this point is called the centre of the circle.

The **Diameter** of a circle is a straight line drawn through the centre and terminated both ways by the circumference.

The **Radius** of a circle is the distance from the centre to the circumference and is equal to half the diameter.

The **Arc** of a circle is any part of the circumference.

A line adjoining the ends of an arc is called the **Chord** of that arc.

A **Segment** of a circle is the figure contained by the arc and its chord. (See shaded portion of the circle.)

A **Degree** is equal to $\frac{1}{360}$th part of a circle. An angle containing 90 degrees is a quarter of a circle, and it is also a right angle.

A **Hexagon** is a six-sided figure having all its sides and all its angles equal.

PLANE GEOMETRY

The following problems in Plane Geometry will often be found useful in the shop when marking off castings or forgings for machine work. They will at the same time afford practice to the beginner in the use of the necessary equipment for drawing.

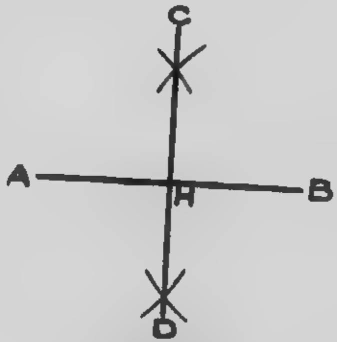
The plates to be drawn in this course will consist of a rectangle measuring 17 ins. × 11 ins. divided into twelve smaller rectangles, four across and three down. One problem is to be placed in a central location in each division, with number of problem placed at bottom of that division. Number of plate is to be placed at top of drawing at the right side. and name and station must be placed at right bottom corner of plate.

All given lines and points, and all lines and points required to be found, must be drawn heavy. All construction lines must be shown, but drawn lightly.

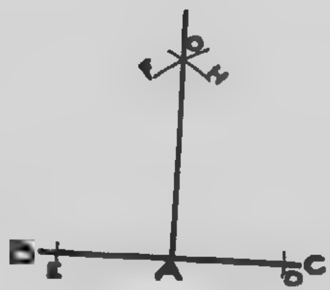
To proceed with Plate 1, lay off rectangle measuring 17 ins. × 11 ins. as before instructed, dividing same into twelve divisions. Turn to Problem 1 in this book, read directions for drawing same carefully, and proceed, performing each operation in its proper order. It is not necessary that you show any dimensions or letters on any problem in Plane Geometry. Draw each problem as large as can possibly be placed in the division. The larger they are drawn, the more accuracy will be obtained.

After completion of problem print the word PROBLEM and its number underneath in letters ⅛ in. high.

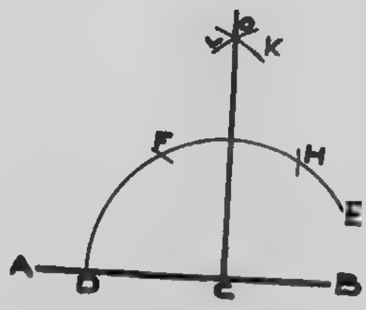
Complete Problem 2 in the same manner, and so on until end of Problem 12, which completes Plate 1, which, after having been marked with your name and station, must be carefully filed away.



PROB. 1.



PROB. 2.



PROB. 3.

Problem 1. To bisect a given straight line AB into two equal parts.

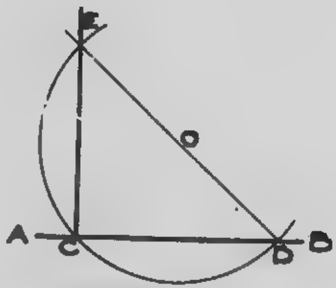
Solution: With A as a centre and any radius greater than half the line describe an arc as shown. With B as centre and the same radius describe a second arc. Draw a straight line CD through the points where the two arcs cross each other, cutting the line AB at H. AH and BH will be equal, and AB is divided into two equal parts.

Problem 2. From a given point A in the given line BC, to erect a perpendicular.

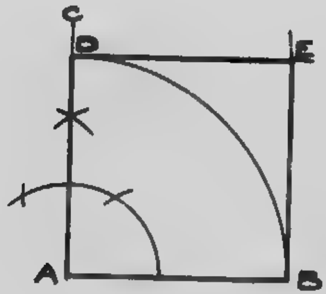
Solution: With A as a centre and any radius less than AC or AB, cut AC and AB at D and E. With D and E as centres and a longer radius describe the arcs F and H. Draw a line through the point O where the arcs cut to the point A. This line OA will be perpendicular to BC.

Problem 3. From the point C at or near the end of the line AB to draw a line perpendicular to the line AB.

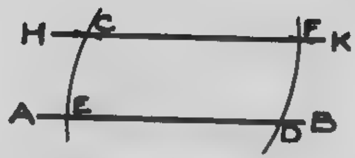
Solution: With C as a centre and any convenient radius describe an arc DE. With D as a centre and the same radius cut the arc DE at F. With F as a centre cut the arc DE again at H and describe another arc K. With H as centre describe the arc L cutting K. Draw a straight line from the point C to the point O where arcs L and K cut. The line OC will be perpendicular to the line AB and the angle OCA will be a right angle.



PROB. 4.



PROB. 5.



PROB. 6.

Problem 4. This problem shows a second method of solving problem 3.

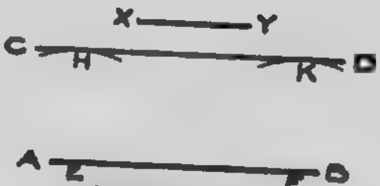
Solution: From any centre O, with the distance OC as radius, describe a circle cutting AB at D. Through the points O and D draw a line cutting the circle at E. Draw a straight line joining E and C, and this line EC will be perpendicular to the line AB.

Problem 5. Upon a straight line AB to erect a square.

Solution: From the point A on the given line AB erect the perpendicular AC. With A as a centre and AB as a radius cut AC at D. With the same radius and D and B as centres describe two arcs cutting each other at E. Join ED and EB, and the figure ABED will be a square.

Problem 6. Through the given point C to draw a line parallel to the given line AB.

Solution: In AB take any point D, and with D as a centre and DC as radius, describe the arc CE. With C as a centre and same radius CD describe the arc DF. Measure EC and make DF equal to CE. Through CF draw a line HK, which will be parallel to AB.



PROB. 7.

PROB. 8.

PROB. 9.

Problem 7. To draw a straight line CD which will be parallel to a given line AB and at a given distance XY from the line AB.

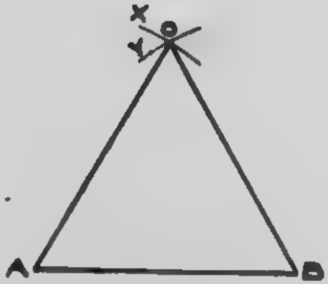
Solution: On the line AB take any two points E and F as centres, and the given distance XY as radius, and describe the arcs H and K. Draw a line CD touching tops of these arcs, which will be parallel to the given line AB and the given distance XY from it.

Problem 8. To bisect a given angle, that is, to divide it into two equal parts. Let ABC be the given angle.

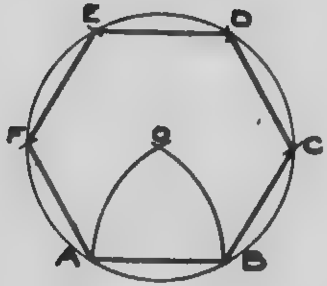
Solution: With B as a centre and any radius BX describe the arc XY. From the points X and Y as centres and the same or greater radius describe two arcs cutting each other at O. Join OB and this line will bisect the angle ABC.

Problem 9. From a given point A on a given line BC, to draw a line making an angle of 60 degrees with the given line.

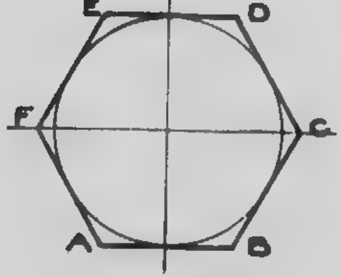
Solution: With A as a centre and any convenient radius describe the arc XY cutting the line BC at Y. With Y as a centre and the same radius cut the arc XY at E. Draw a line from A through E, and the angle CAE will be an angle of 60 degrees.



PROB. 10.



PROB. 11.



PROB. 12.

Problem 10. With a straight line AB as a base, to construct an equilateral (equal-sided) triangle.

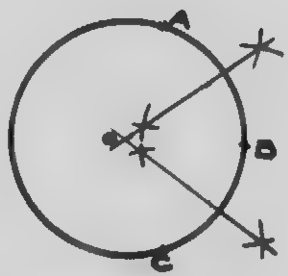
Solution: With A as centre and AB as radius describe the arc X, and with B as a centre and the same radius describe another arc Y cutting X at O. Join AO and BO and the triangle ABO will be an equilateral triangle.

Problem 11. On a straight line AB to construct a hexagon.

Solution: With A and B as centres and AB as a radius, describe two arcs cutting each other at O. With O as a centre and the same radius describe a circle passing through A and B. With the same radius and starting from B, mark off four divisions on the circumference of the circle at C, D, E, and F. Join BC, CD, DE, EF, and FA, and the figure ABCDEF will be the required hexagon.

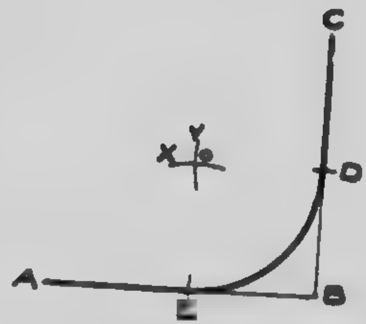
Problem 12. Draw a hexagon outside of a given circle by means of tee-square and set-squares (60 degrees).

Solution: Using the tee-square, draw two horizontal lines touching top and bottom of circle. Place the 60 degree set-square on edge of tee-square and draw sidelines DC and AF, touching outside of circle. Reverse set-square and draw the lines EF and BC, also touching outside of circle. The figure ABCDEF will be a hexagon. This method is most commonly used in drawing a hexagon.



PROB. 13.

PROB. 14



PROB. 15.

Problem 13. To construct a circle to pass through three given points A, B, and C.

Solution: Join AB and BC and bisect them, the perpendiculars cutting at O. From O as a centre and OA as radius describe a circle which will pass through the three given points ABC.

Problem 14. To divide a straight line into any number of equal parts.

Example: Divide AB into 5 equal parts.

Solution: To divide the straight line AB into five equal parts, draw the line AC at any angle. From the point A, with compasses set at any radius, mark off five divisions on the line AC and join the fifth to B. Draw lines from each division on AC to AB parallel with the line 5B, and these parallels will cut AB into five equal parts.

(Note:—Use set-square to draw parallel lines.)

Problem 15. When two given lines form a right angle, as in ABC, to draw a circular arc joining them from a point D on BC.

Solution: With B as a centre and BD as radius describe an arc E on the line AB. With E and D as centres and same radius, describe arcs X and Y, cutting each other at O. With O as a centre and same radius draw curve DE, joining the lines CD and EA.

Note:—This method is often used in mechanical drawing, when showing filleted or rounded corners.

PLANE GEOMETRY—(Continued)

The following problems in Plane Geometry are combinations of those previously given. There are, therefore, no sketches or explanations shown

Problem 16. Draw an angle of 30 degrees.

Problem 17. Draw a circle and construct within it an equilateral triangle, each corner of which touches the circumference of the circle.

Problem 18. Construct a hexagon, with tee-squares and set-squares, measuring 2 ins. across flats.

Problem 19. By means of principles illustrated in problem 14, lay off the radii of two gears, whose diameters bear a ratio of 3 to 2.

Problem 20. Construct an angle of 75 degrees.

Problem 21. Locate a point on the line AB which shall be equidistant (an equal distance) from the points D and C, point C being 3 ins. above one end of line, and point D 1 in. above other end of line.

Problem 22. Construct, without using tee-squares or set-squares, a rectangle measuring 3 ins. x 2 ins.

Problem 23. Locate centre of a given circle 3 ins. in diameter, as if unknown.

Problem 24. Within an equilateral triangle having 3-inch sides, construct a circle whose circumference touches each side of the triangle.

EXERCISE No. 1

1. Print with standard letters 1/8″ high the definitions of words, Diameter, Radius, Diagonal, and Degree.

2. Construct a right angle, and mark off angles of 60°, 45°, 30°, and 15°.

3. Draw a line 3¼″ long and divide it into nine equal parts without use of scale.

4. Construct a right-angle triangle, base measuring 3¼″, and hypothenuse 4¾″.

5. Construct a square having a diagonal of 2¾″ long.

6. Circumscribe a circle about a triangle having sides 2½″ long.

7. Draw a semi-circle having a radius of 1½″ and divide this into angles of 15° each.

8. In an angle of 60°, draw a fillet with a 1¼″ radius.

9. Construct an equilateral triangle having an altitude of 3″.

10. Construct a triangle containing angles of 90°, 60°, and 30°.

11. Construct a rectangle having sides 2½″ long and diagonal 3½″ long.

12. The perimeter of a triangle is 7½″. Draw same, marking length of each side.

EXERCISE No. 2

1. On a line 1½" long construct a hexagon.

2. On a straight line 2" long construct a square.

3. Construct an octagon within a circle 2¾" in diameter.

4. Draw a four-sided figure having a diagonal of 4" long and sides measuring 2", 2½", 2¾", and 3" long.

5. Construct a pentagon inside a circle 2½" in diameter.

6. Construct an ellipse inside a rectangle measuring 3" by 2" (any method).

7. Within a triangle having sides 3", 2½", and 2¼" long draw a circle tangent to each side.

8. Construct a four-sided figure having angles of 60°, 75°, 105°, and 120°.

9. Construct a triangle having an altitude of 2" and angles of 60°, 45°, and 75°.

10. Lay off a radius of two gears whose diameters have a ratio of 7 to 3.

11. Construct a rectangle having a diagonal of 3½" long and sides are in ratio of 2 to 1.

12. Construct an angle of 135°.

MECHANICAL DRAWING

Projections

All drawings made with the use of squares and instruments, and based upon the principles of Orthographic Projection, are called Mechanical Drawings.

Such drawings explain the shape and size an object is desired to be much better than a long verbal explanation.

In order to represent an object upon paper by means of Orthographic Projection, it must be clearly understood at the beginning that each line is seen directly from the front or from above (other positions will be considered later), and not as they appear to the eye, as is the case in a perspective drawing (or pictorial view), which are drawn from one point of view only.

The simplest form of Orthographic Projection (hereafter this term will be shortened to the word projection) is in representing an object on two planes at right angles to each other. These planes are known as the Vertical and the Horizontal Planes.

Upon the Vertical Plane is drawn a view known as the "Elevation," and represents the object's vertical appearance, or what is seen by looking at the object directly from the front.

Upon the Horizontal Plane is drawn a view known as the "Plan," and is a drawing representing what is seen when looking down upon the object from above.

Other views upon different planes are frequently used, but the principle of projection, as applied to the plan and elevation upon the horizontal and vertical planes, is the same, and can easily be followed later when required.

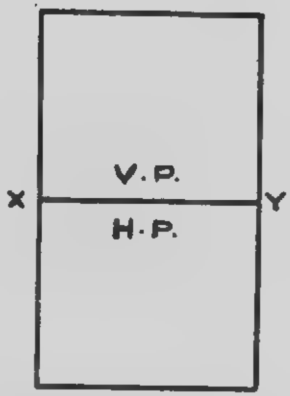


FIG. 18
REPRESENTS A PLANE SURFACE

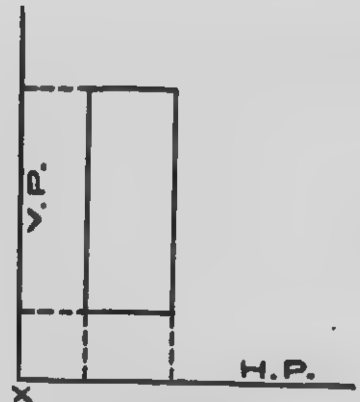


FIG. 19
REPRESENTS THE V.P. AND H.P. WITH OBJECT IN FRONT OF V.P. AND ABOVE H.P.

To illustrate the methods used in projecting the plan and elevation of any object upon a plane surface, proceed as follows:

Take a sheet of paper (see Fig. 18) and fold it in two, so that when looking at it on end the edges form a right angle (see Fig. 19).

The junction of the two planes is called the ground line, and in this case is represented by the line XY in Figs. 18 and 19.

The object used in the first lesson is what is called a cylinder, and is similar to a round pencil before being sharpened.

Place yourself directly in front of the two planes in their proper position, and hold this cylinder so that its centre line or axis is parallel to the Vertical Plane (V.P.) and at right angles to the Horizontal Plane (H.P.). Hold it so that it is just a short distance in front of the V.P. and a little above the H.P.

Looking at this object from where you are now (from the front) you see the elevation. This, it will be noticed, consists of two long vertical lines representing the sides of the cylinder, and two short lines at top and bottom representing the sides of the cylinder, and two short lines at top and bottom representing the ends, all four lines forming a rectangle same length and width as the object, and shown on the V.P.

Still keeping the object in the same position, look down upon it from above, when all that will be seen is the end of the cylinder, which is represented by a small circle drawn upon the H.P., and is the plan of the cylinder in its present position.

Had it been possible to trace these upon the planes which were behind and below the cylinder, and then flattened the planes out into a plane surface again, a drawing as is seen in Fig. 20 would have been the result.

The drawing made above the ground line XY, i.e., upon the V.P., as already explained, is called the elevation, and the drawing made below the line XY, on the H.P., is called the plan.

It will be seen that the circle is directly underneath or in line with the elevation, also that the distance A above the ground line, and B below the ground line, correspond with the distances the cylinder was held in front of and above the two planes.

To make drawings upon two planes at right angles to each other would be very inconvenient, yet in imagination all objects are pictured as being in front of and above the two planes, and represented in these positions upon a flat surface.

To ensure that the views are in line with each other, projection lines are drawn from the one view to the other. These projection lines are always drawn at right angles to the ground line.

Whenever a circle is drawn, two centre lines should be drawn through same at right angles to each other, and whenever a cylindrical object is drawn, one centre line should be running through its centre. Embodying these points into the last problem, the drawing would appear as shown in Fig. 21.

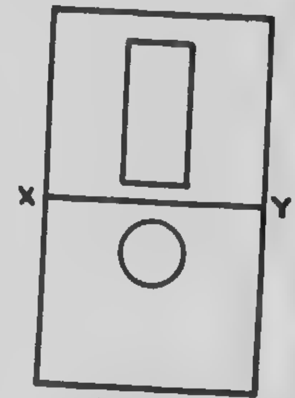


FIG. 20

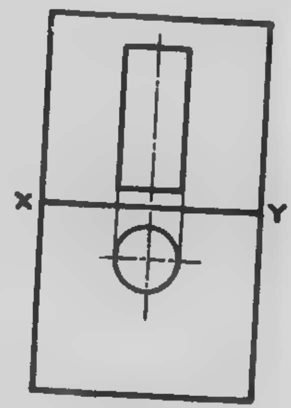


FIG. 21

It might be of advantage to enumerate at this stage the points which have been brought out when following up the explanation and drawing out of this example, as they are common to all mechanical drawings and should be thoroughly understood.

1st. It has been shown that upon a paper representing a plane surface two views have been drawn, each on a different plane.

2nd. The names of these planes are the Vertical and the Horizontal, and upon them have been drawn the views known as the elevation and the plan.

3rd. The ground line (XY) is the intersection of the two planes.

4th. The distance the views are clear of the ground line shows how far in front of and above the two planes the object has been placed.

5th. One view alone does not show the shape of such an object, but the two have to be considered together.

6th. Projection lines from one plane to another ensure that views are properly placed.

7th. Two centre lines at right angles to each other are required for circles, and one centre line for cylindrical objects.

To convey a correct idea of the position of any object, it is necessary to define the position of it in relation to the different planes.

For instance, in the example given, the position of the cylinder (represented by a model, or a round, unsharpened pencil) is that its centre line (or axis) is parallel to the V.P. and perpendicular to the H.P.

A little study of each position is necessary, preferably with a model in hand, before attempting the first lessons; afterwards they can be seen in imagination.

Applying the same principles of projection as explained, the following objects placed in the positions named will afford good drawing practice and drive home the lessons (see Fig. 22).

A—CYLINDER

B—RECTANGULAR PRISM

C—TRIANGULAR PRISM

D—PYRAMID WITH SQUARE BASE

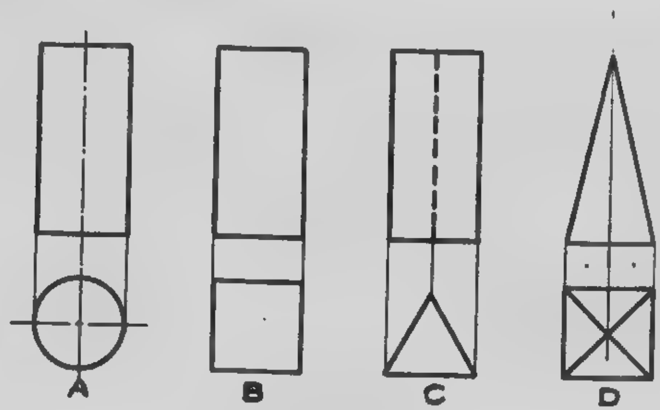


FIG. 22

When commencing a problem, first study carefully the shape of the object given, then its position in relation to the planes.

Make each model drawn about 2½ ins. long and 1 in. wide.

In some of the positions named certain lines will not be visible when looking at the object from above to secure the plan, or from the front to obtain the elevation. In all such cases, when a line is hidden, show it with a dotted line as shown in Fig. 22.

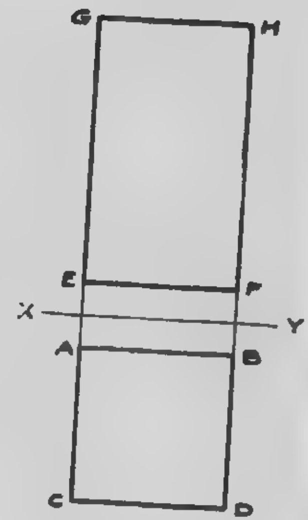
PROBLEM 1

Draw the plan and elevation of a rectangular prism, when its base is parallel to the H.P. and one side is parallel to the V.P. Object is ¼ in. clear of both planes.

Solution: First draw the ground line XY. In this case this should be about 2 ins. from bottom of division, in order that the drawing be centrally located.

After a careful study of the position named, it will be found that the plan is simply a square the same size as end of prism. This is then drawn as shown at ABCD, and is ¼ in. clear of the ground line. Next, by means of using set-square resting on tee-square, erect perpendiculars from A and B up into the vertical plane, to represent sides of the prism as seen when looking from the front. The line EF is drawn next, ¼ in. clear of the ground line. From this line the height of the prism is laid off on the perpendicular projection lines, and after drawing the line GH the drawing is completed.

Note. Object lines (those representing shape of the object), including dotted lines, should be drawn in heavy. Centre lines, projection lines, construction lines, and ground lines, are drawn in lightly.

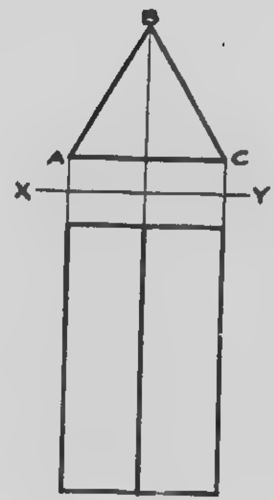


PROB. 1

PROBLEM 2

Draw plan and elevation of a triangular prism, when its base is parallel to the V.P. and one side is parallel to the H.P. Object is ¼ in. clear of both planes.

Solution: In this case the plan will be the largest view and the ground line must therefore be well above the centre of the division, or about 2 ins. from the top of the division. The elevation, which must first be drawn, in this case will be an equilateral triangle with one side parallel to the ground line. This is represented by ABC. Projection lines must then be drawn down from points A, B, and C, and height of prism marked off, to represent the plan. After drawing in the object lines heavy, the drawing is complete.



PROB. 2

Solutions or sketches will not be given for the remainder of the problems comprising first half of Plate 3. The pupil should, if possible, solve these without assistance.

Problem 3. Draw plan and elevation of a cylinder, when its base is parallel to the V.P. and its centre line is parallel to the H.P.

Problem 4. Draw plan and elevation of a pyramid with a square base. Its centre line is parallel to the V.P. and its base is parallel to the H.P. One edge of the base is parallel to the V.P.

Problem 5. Draw plan and elevation of a triangular prism when its base is parallel to the H.P. and the side closest to the eye is parallel with the V.P.

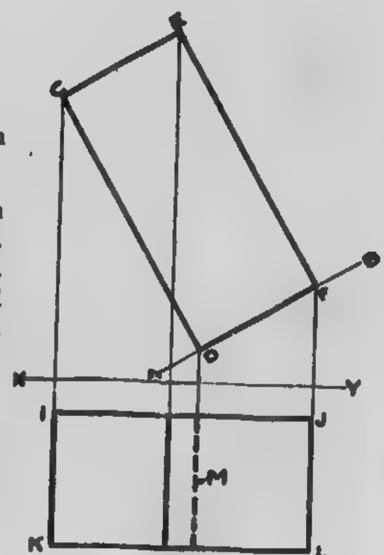
Problem 6. Draw plan and elevation of a rectangular prism when its base is parallel to the V.P. and one side is parallel to the H.P.

PROBLEM 7

Draw plan and elevation of a rectangular prism when its base is inclined at an angle of 30 degrees to the H.P. and one side is parallel to the V.P.

Solution: First draw ground line, 2¼ ins. from bottom of division. As the plan in this case must be projected down from the elevation, the latter must be drawn first. Draw the line AB to represent the base inclined at 30 degrees (use 60-degree set-square). Next turn set-square over and draw the line CD at right angles to AB, which would make it at an angle of 60 degrees with the ground line. Mark off width of prism and draw line EF parallel to CD. Mark off height and draw line CE parallel with AB. After object lines have been drawn in heavy, this completes the elevation.

To draw the plan, first draw lines IJ and KL, to represent width of prism. Projection lines are then drawn down from elevation as shown. Lines visible when looking down upon the object are drawn in full, and those not visible are dotted, as shown at M. After object lines have been drawn in heavy, the whole drawing is complete.



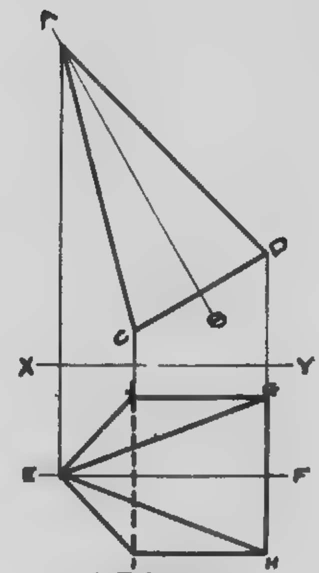
PROB. 7

PROBLEM 8

Draw plan and elevation of a pyramid 2½ ins. in height and having a base 1¼ ins. square, when its centre line makes an angle of 60 degrees with the H.P., one edge of base is parallel to V.P., and centre line is also parallel to the V.P.

Solution: First draw ground line XY about 2¾ ins. from bottom of division. Next draw centre line AB inclined at 60 degrees to XY and lay off upon it height of pyramid, 2½ ins. Draw CD at right angles to AB to represent the base and mark off to the proper size, 1¼ ins. Join CA and DA, thus completing elevation.

To draw the plan, first draw centre line EF. Next project a line down from D in the elevation. Mark off on this line G and H, representing width of base. Project lines down from A and C in the elevation. Using the tee-square, lines are now drawn joining HI and GJ. Lines must now be drawn joining points EJ, EG, EH, and EI. After drawing in all object lines heavy, the drawing is completed.



PROB. 8

Problem 9. Draw plan and elevation of a rectangular prism when its base is parallel to the V.P. and diagonal across the base is at right angles to the H.P.

Problem 10. Draw plan and elevation of a rectangular prism when one side makes an angle of 45 degrees with the V.P. and another side is parallel to the H.P.

Problem 11. Draw plan and elevation of a triangular prism when one side makes an angle of 60 degrees with the H.P. and one edge is parallel to the V.P.

Problem 12. Draw plan and elevation of a pyramid with a square base, when its centre line is inclined at an angle of 45 degrees to the H.P. and parallel to the V.P., and the diagonal across its base is at right angles to the V.P.

Hitherto these lessons have only considered the drawing of objects when seen from the front (front elevation) and from above (the plan).

Frequently these two views are insufficient to convey a clear meaning of the shape of an object, in which case there are two more views sometimes used and which we will now consider, namely, the side elevation, frequently called the end view, and section views.

An end view, as the name implies, is what is seen when looking at the end or from the side of the object. In drawing an end view (or side elevation) project it from the front elevation or vice versa, as best suited to the particular case under consideration. This saves time, as it is usually only necessary to take measurements for one view.

The following drawing of a hexagonal prism shows plan, front elevation, and side elevation. The plan is drawn first, projection lines are then brought up for front elevation and length of prism marked off. The side elevation is shown to the right, and is drawn by projecting lines from front elevation to show height, and taking width across flats from plan. The two lines XY mark the divisions between the three planes.

To draw the plan, the object is looked at from above, as shown at A. For the front elevation, the object is looked at from the front, as shown at B, and for the side elevation from the side, as shown at C.

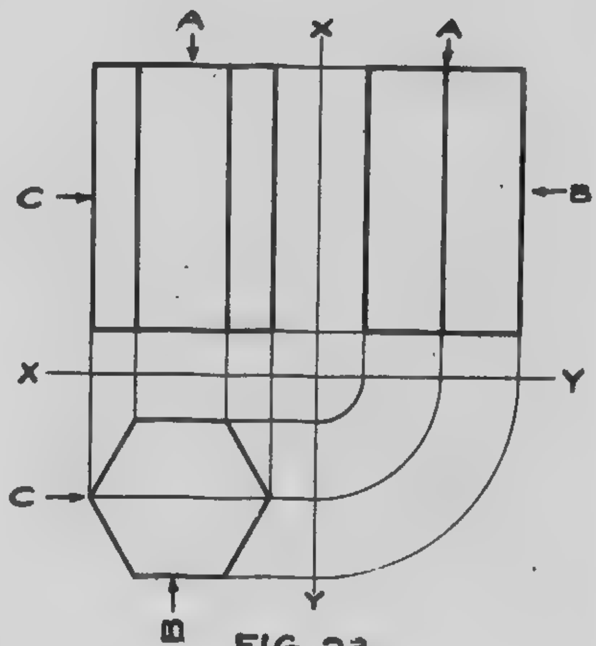
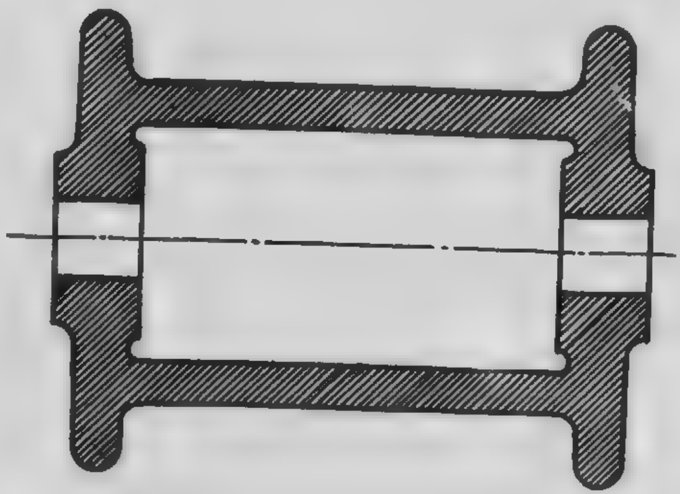


FIG. 23

A section view shows what is seen when the object is supposed to be cut, usually through the centre, leaving a level surface.

The following example, showing a rope drum for travelling crane, illustrates method of showing section. The front elevation and end view are given, the former being a section view. In a drawing like this the end elevation would be drawn first, and all diameters projected over into front elevation by means of tee-square.


SECTION THROUGH A.B.

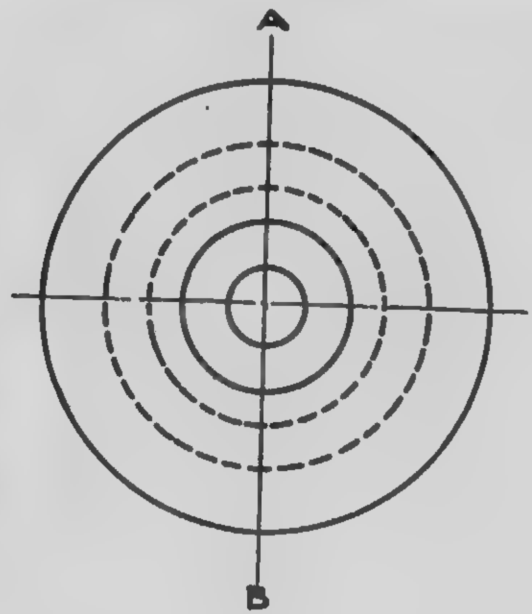


FIG. 24

PROBLEM 13

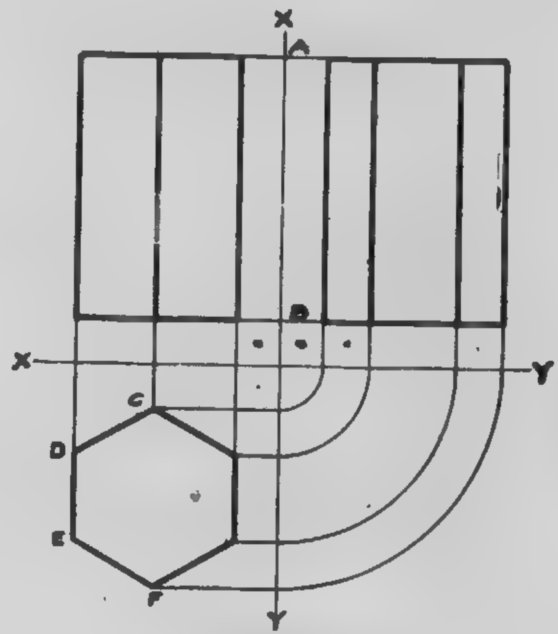
Draw plan, front elevation, and side elevation of a hexagonal prism measuring 1½ ins. across corners and 2 ins. long, when it is in the following position:

Centre line is parallel to the V.P.; base is parallel to the H.P. The surfaces of two sides are at right angles to the V.P.

Solution: First draw two ground lines XY at right angles to each other to represent division of planes. Next draw plan and front elevation.

To draw side elevation, take tee-square and project (from front elevation) top and bottom of prism to side elevation, as shown at A and B.

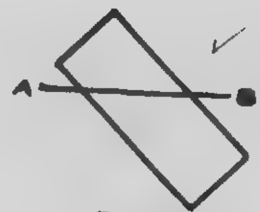
Next project points C, D, E, and F from the plan over to the vertical ground line XY. From here project (by using compass with point where ground lines cross as centre) these points up to horizontal ground line XY, from where they are projected up to form sides of prism in side elevation.



PROB. 13.

Problem 14. Sketch shows front elevation of a triangular prism 2½ ins. long with sides 1 in. wide. One side makes an angle of 45 degrees with H.P., and centre line is parallel with V.P. Draw plan, and show section of the line AB.

Problem 15. Sketch shows plan of a cast-iron pipe, 2½ ins. outside diameter and 1½ ins. inside diameter. Pipe is 2 ins. long. Draw front elevation, showing section on the line AB, which is ¼ in. below centre of plan.



PROB. 14

PROB. 15

Problem 16. Draw the necessary views to show a cast-iron pipe 2½ ins. long and 2 ins. outside diameter, inside diameter being 1¼ ins. Show a section on view showing length of pipe.

Problem 17. Draw plan, front elevation, and side elevation of a hexagonal prism measuring 1½ ins. across corners and 2 ins. long, when its centre line is parallel to the V.P. and one of its sides makes an angle of 45 degrees with the V.P. Its base is parallel to the H.P.

Problem 18. Draw plan, front elevation, and side elevation of a pyramid which is 2½ ins. long and has a base 1½ ins. square. Its centre line is parallel to the V.P. and makes an angle of 60 degrees with the H.P. A diagonal drawn across the base is at right angles to the V.P. Mark a point on centre line 1½ ins. down from top of pyramid. Through this point draw a horizontal line AB. Show in the plan a section on the line AB.

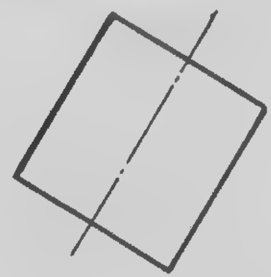
Problem 19. Draw plan, front elevation, and side elevation of a pyramid 2 ins. long, with a triangular base having 1½ in. sides, one of which makes an angle of 45 degrees with the V.P. Its base is parallel to the H.P., and centre line is parallel to the V.P.

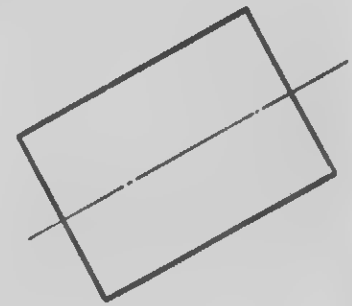
The following five pages contain problems in projections, with one view shown. The student will draw this view and project from it the missing view.

RECTANGULAR PRISM

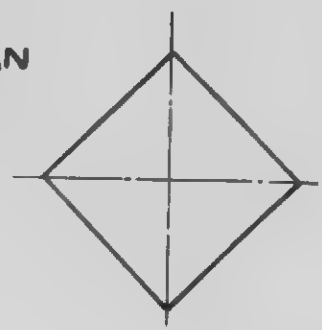
HEIGHT 3" BASE 1½"

DRAW ELEVATION HERE





DRAW PLAN HERE

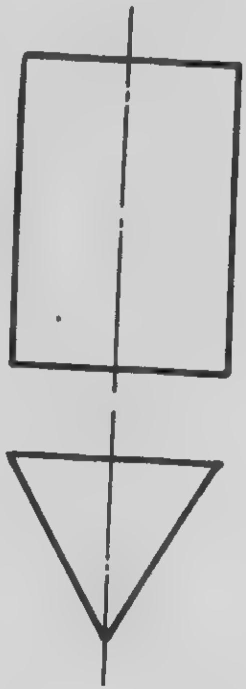


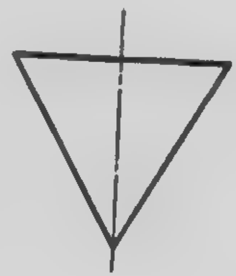
DRAW PLAN HERE

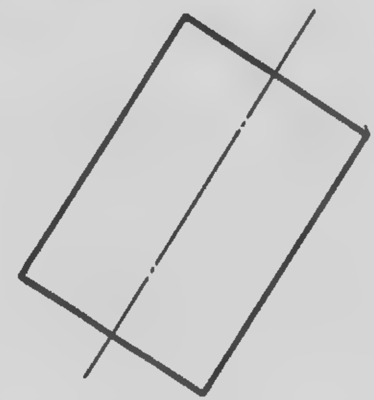
DRAW PLAN HERE

EQUILATERAL TRIANGULAR PRISM

HEIGHT 3" BASE $1\frac{1}{2}$"







DRAW PLAN HERE

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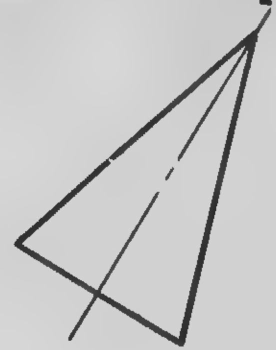
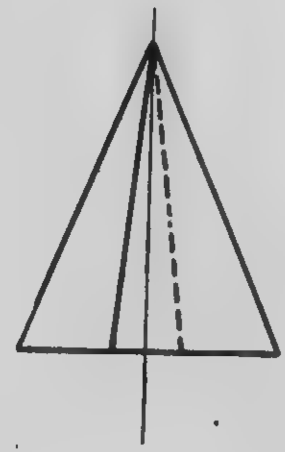
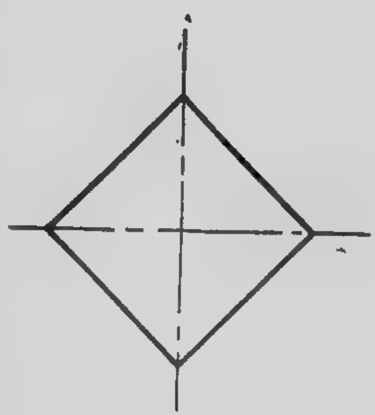
SQUARE PYRAMID

HEIGHT 3" BASE 1½" SQUARE

DRAW ELEVATION HERE







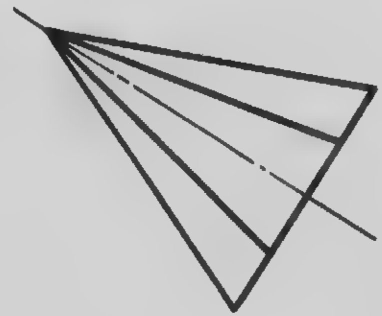
DRAW PLAN HERE

DRAW PLAN AND DETERMINE ANGLE OF BASE TO THE VERTICAL PLANE

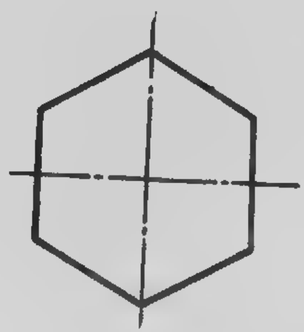
HEXAGONAL PYRAMID

HEIGHT 3" X 1½" ACROSS FLATS

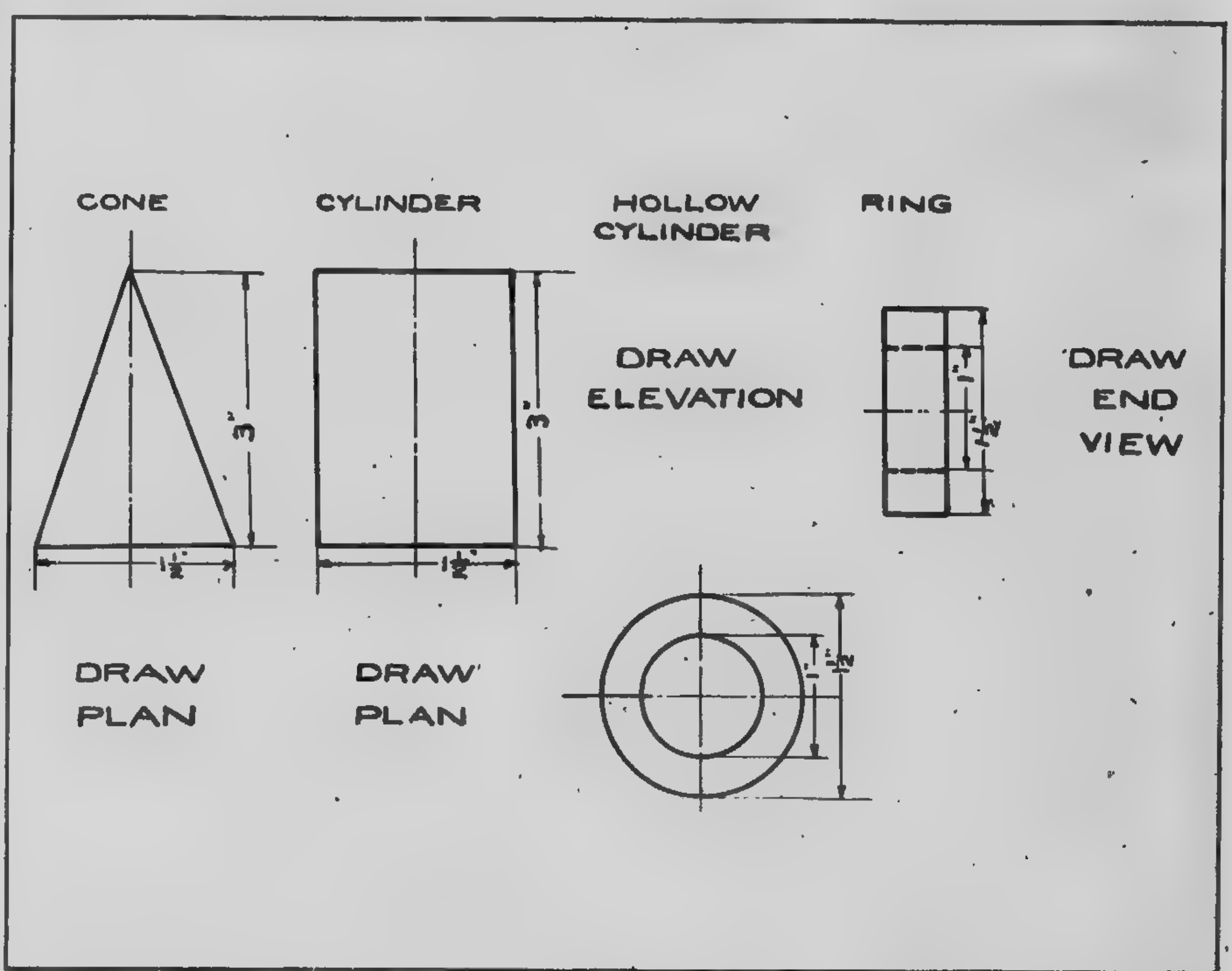
DRAW
ELEVATION



DRAW
PLAN



DRAW
PLAN


CONE
CYLINDER
HOLLOW CYLINDER
RING
3"
3"
1½"
1½"
DRAW ELEVATION
DRAW END VIEW
DRAW PLAN
DRAW PLAN

After practising the following five exercises arrange them neatly on standard sheet.

Exercise No. 1. Draw the plan and front elevation of a rectangular prism, when its base is parallel to the H.P. and one side is parallel to the V.P. The dimensions of the prism are 2¾" x 1½" x 1". 1½ x 1 x 3

Exercise No. 2. Draw the plan and 4 elevation of a cylinder 3" x 1⅞" diameter, standing with base parallel to the H.P. and its centre line perpendicular to the H.P.

Exercise No. 3. Draw the plan and elevation of the cylinder described in Exercise No. 2, lying with its centre line (called the axis) parallel to both planes.

Note.—Do not fail to place the centre lines on your drawing where needed.

Exercise No. 4. Draw the plan and elevation of a triangular prism having its three faces perpendicular to the H.P. and one face parallel to the V.P.

Note.—The end view of this prism is that of a 1½" equilateral triangle.

Exercise No. 5. Draw the plan and elevation of a cone standing with its base parallel to the H.P. The cone is 3" high and the base is 1⅞" diameter.

The following exercises will be placed on a standard sheet. Make each model drawn about 2½" long and 1" wide.

Exercise No. 6. Draw plan and elevation of a rectangular pyramid having a square base parallel to the H.P. and one edge of the base parallel to the V.P.

Exercise No. 7. Draw plan and elevation of a triangular prism, when its base is parallel to the V.P. and one side is parallel to the H.P.

Exercise No. 8. Draw plan and elevation of a cylinder, when its base is parallel to the V.P. and its centre line is parallel to the H.P.

Exercise No. 9. Draw plan and elevation of a rectangular prism when its base is parallel to the V.P. and one side is parallel to the H.P.

Exercise No. 10. Draw the plan and elevation of a cube 2½" x 2[illegible]" x 2½".

In many problems in drawing it is necessary to draw one certain view first, as the other view cannot be drawn to the correct size without being able to get the proper dimensions by projection. This is well illustrated in the next two exercises.

The following problems will be placed on standard sheet:

Exercise No. 11. Draw the plan and elevation of a hexagonal prism 3" high and 2⅝" across corners. One face is parallel to the V.P. and the base is parallel to the H.P.

Exercise No. 12. Draw the plan and elevation of a hexagonal prism 2¾" long and 2⅝" across flats.

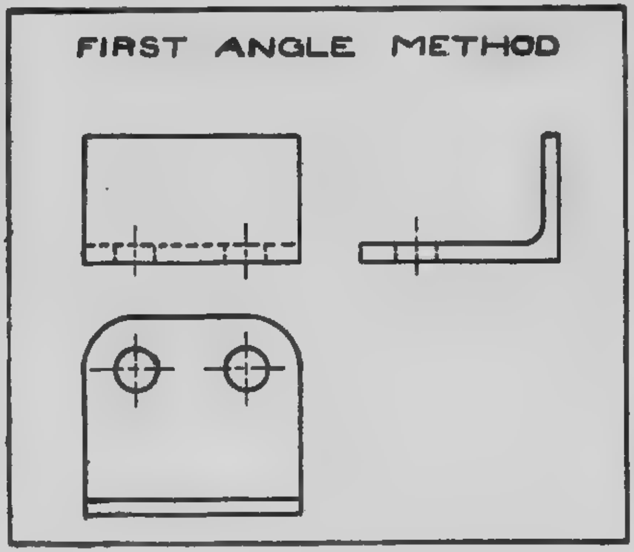
Exercise No. 13. Draw the plan and elevation of a rectangular prism standing with its base parallel to the H.P. and its sides at an angle of 45° to the V.P.

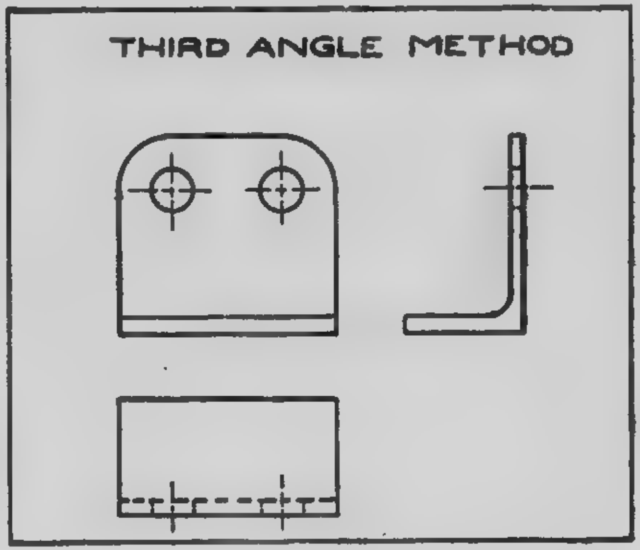
Exercise No. 14. Draw the plan and elevation of a rectangular pyramid, axis perpendicular to the H.P. and two edges of the bases 30° to the V.P.

Exercise No. 15. Draw the plan and elevation of a hexagonal pyramid, axis parallel to the H.P. and one edge of base parallel to the V.P.

SYSTEMS OF PROJECTION

In addition to the "**first angle method**" of projecting one view from another, as explained and demonstrated on the foregoing pages, there is another method used extensively called the "**third angle method.**" The views on this page will clearly demonstrate the two methods to the student, and he will note that the difference between the two methods is, in its results, simply a question of the relative arrangements of the views.





Sketching

It will be necessary in doing the exercises that follow to first make a freehand sketch of the subject for each plate before attempting to draw it on the standard drawing sheet. The making of the freehand sketch is just as important as the mechanical drawing, and will be given close scrutiny by the Instructor. All freehand sketches must be done in an orderly manner in your sketch book.

Hidden Surfaces

In mechanical drawing it is constantly necessary to show, by some means, surfaces or details of parts that are hidden from view behind the surface shown by solid or fu[illegible] lines.

Unless th[illegible] urfaces could be indicated by some simple means it wo[illegible] en be necessary to make additional views to show cle[illegible] the shape of the object.

The method commonly used to indicate these hidden surfaces is to draw them in, in the proper positions, but to use lines formed of short dashes. These broken lines, or "invisible lines," as they are sometimes called, have a distinctly different appearance from the solid outlines of the rest of the drawing, and their meaning is readily understood.

Sectioning

When making drawings it is often necessary to show a view of the piece with part cut away, or "in section," as it is called.

The advantage of this plan is that it helps to show the shape of the piece more clearly, and often the dimensions can be placed to better advantage.

As an aid in indicating that a piece is in section, the surface cut is covered with light lines called section lines or "cross-hatching." These lines are ruled with the 45° triangle resting on the T-square, and the spacing is a matter of judgment.

The triangle is moved along the T-square, and the spacing accomplished by the eye. It is customary to use finer cross-hatching on small pieces.

Where two or more pieces assembled together are shown in section, the different parts are shown more clearly by sloping the section lines in opposite directions for each part.

Where no special section is indicated, it is usually understood that the cut is taken along the centre line of the view.

Further on in the book a page is given over to illustrating different patterns of cross-hatching used to signify the various kinds of material. These are arbitrary and by no means standard in the various draughting rooms, and need not be [illegible] died to any great extent at this stage of our work.

Unfinished Views

You will find in many of the exercises following that some of the views are finished completely and others only partially, making it necessary for you to exercise your imagination in order to complete the unfinished views in a satisfactory manner.

Study each problem carefully, and try to produce a drawing finished in every respect. Certain of the lines left off of the unfinished views are hidden surface lines, others are solid lines, consequently the manner in which you complete the views will prove your grasp of the subject.

SIMPLE VIEWS

Secure from the Instructor a model known as a rectangular prism. Study the shape of this prism, for in this lesson we will show how to make a drawing of it.

The drawing done all through this course is done according to the laws of the Orthographic Projection, and after several lessons are completed you will then begin to understand some of these laws, for they determine how we shall arrange the views of the different objects.

In making ordinary drawings, either freehand or mechanical, it is not always possible to properly indicate by a single view the shape of the object being drawn, and for this reason working drawings usually consist of a number of views of the object. Fig. 25 is an incomplete drawing, because the mechanic cannot tell from the drawing whether the piece is square, cylindrical or irregular, looked at from the end.

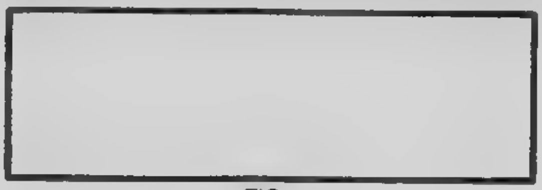


FIG. 25

Fig. 26 shows the completed drawing, and after the end view has been added it is shown definitely that the object was a rectangular prism. The dimensions added give the additional information that the prism is 3in. long, 2in. wide, and 1in. high. Notice how the dimensions are shown with special light lines and arrow-heads.

The light lines running from the one view to the other are called projection lines.

You will notice that in drawing this rectangular prism we only show the outline. What we draw represents the exact outline that would be seen if we were to stand in front of the view and cast our eye directly around the object. In placing the two views, they must be exactly in line, as indicated by the projection lines in Fig. 26 that join up the two views.

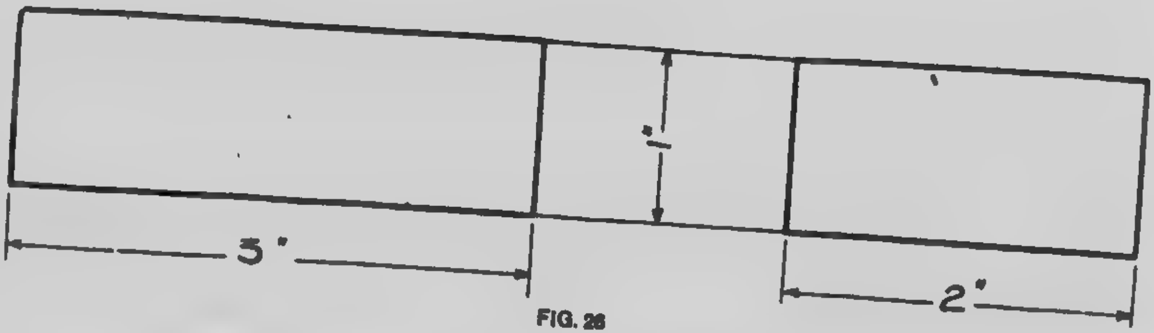


FIG. 26

Pointers

Use a 2-H pencil for all your drawing. To sharpen the lead, slide it back and forth along a piece of sandpaper, rotating it so as to get a slender and rounded point.

The student should be particular about his pencil to see that the point is kept in proper shape. Neat, accurate drawings are a necessity, and properly kept tools are a great aid in producing them.

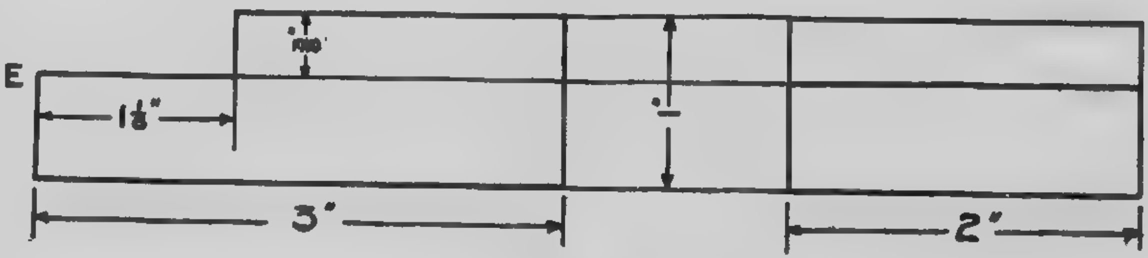
Do everything possible to keep your hands clean, and then it will be easy to keep the paper clean. The drawing paper should be fastened to the board as smoothly as possible, for it is very difficult to do satisfactory work on paper which does not lie flat on the board.

Small thumbtacks are much to be preferred to large ones, as they hold the paper down as well and are more easily pushed into and drawn from the board.

To rule lines properly, the pencil should be held nearly vertical, which keeps the point slightly away from edge of T-square.

Exercise 1. In your sketching book make a freehand drawing of a rectangular prism as shown in Fig. 26. Repeat this exercise several times until you are able to present a neat sketch of this object. Keep the model in front of you for the first time, then repeat from memory.

Exercise 2. Using the drawing, board and tools, prepare a mechanical drawing of the same model, having only your last sketch in front of you as a guide.



SIDE ELEVATION FIG. 27 END ELEVATION

SHOWING BROKEN LINES and NAMES OF VIEWS

Fig. 27 shows an object which is practically the rectangular prism shown in Fig. 26, but after it has had a section removed. The end view being placed to the right of the side view therefore represents the end of the object to the right, marked E in Fig 27.

In making the end view we imagine the object has been turned to the right until a full view of the end marked E is shown. This is the principle we use in placing and forming the end view of all objects.

We must now learn the names applied to the different views. Both these views show the "height" of the object, and any view that shows height is called an **elevation.** Thus we have a side elevation and an end elevation. Suppose that we are looking down on the object from above, then we would see a view as shown in Fig. 28. This view gives the length and width, and is called the **plan.** It will be necessary to remember this, for we will soon have drawings that include a plan view; in fact plans are always drawn when it is desired to show the length and width of an object in one view.

The plan is placed directly below the side elevation and always represents a view of the object as seen from above, that is looking down on the object.

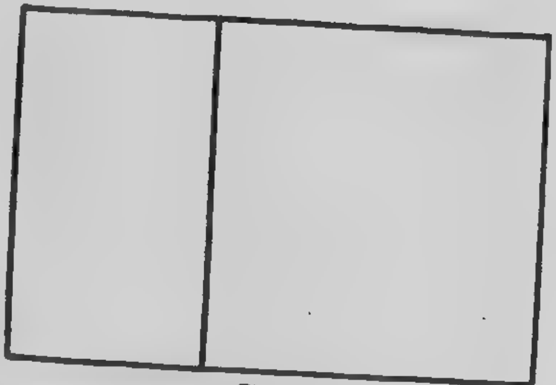


FIG. 28

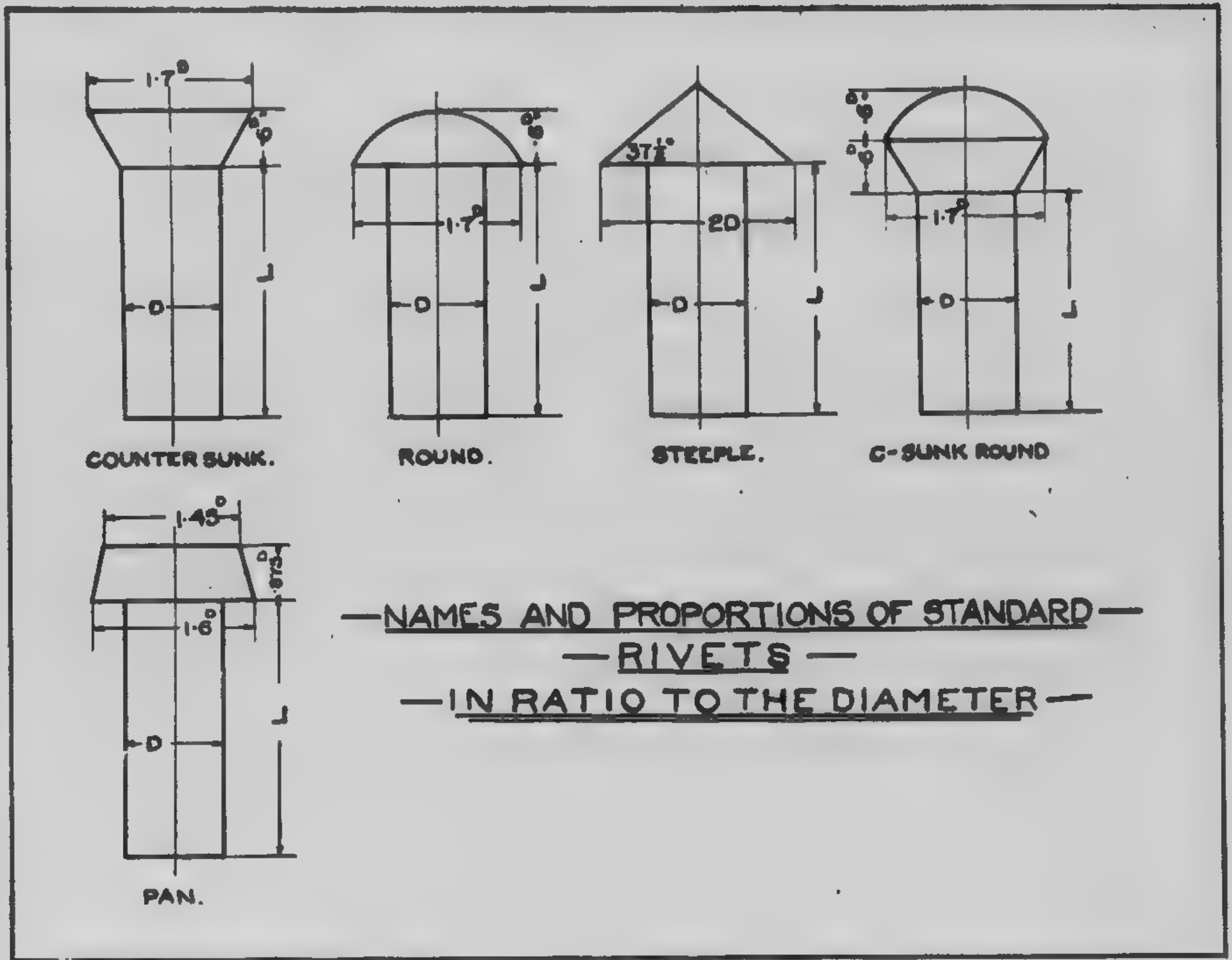
As just mentioned, the elevations are placed directly in line with each other, horizontally, and the plan is in direct line vertically below the side elevation. This follows from the use of projection, and it is well to join up the views by light continuous lines, which we will call projection lines. As you advance in the work you will see how easy it is, by means of light projection lines drawn with the T-square or triangle, to make a new view by projecting over from one view already completed.

Exercise 1. Make a freehand sketch of the drawing shown in Fig. 27. Repeat this, doing so from memory. Be sure you get all the dimensions shown.

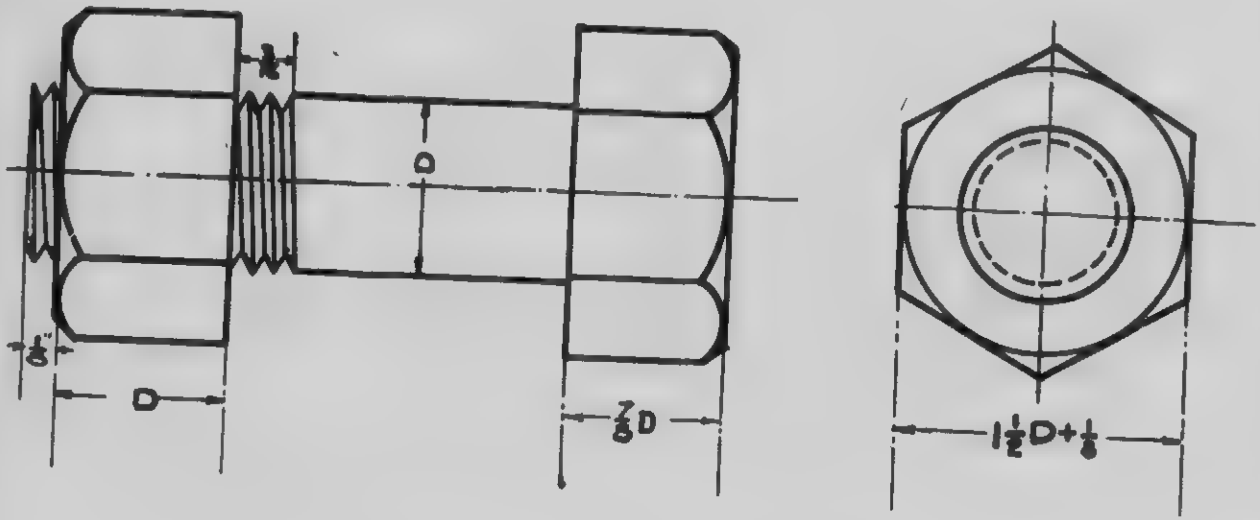
Exercise 2. Make a mechanical drawing from your last freehand sketch.

Exercise 3. Make a mechanical drawing of a rectangular prism measuring $2\frac{3}{8}$in. x $1\frac{7}{8}$in. x $\frac{3}{8}$in. (first make a freehand sketch of the prism, as near to the correct full size as possible, but without the use of your rule). Two elevations will form the required views for this exercise; put in dimension lines.

Exercise 4. A rectangular prism measures $3\frac{1}{8}$in. x $2\frac{7}{16}$in. x $1\frac{5}{8}$in. Draw a side and an end elevation of this prism full size, after first making a freehand sketch. Place in the necessary dimension lines and figures.



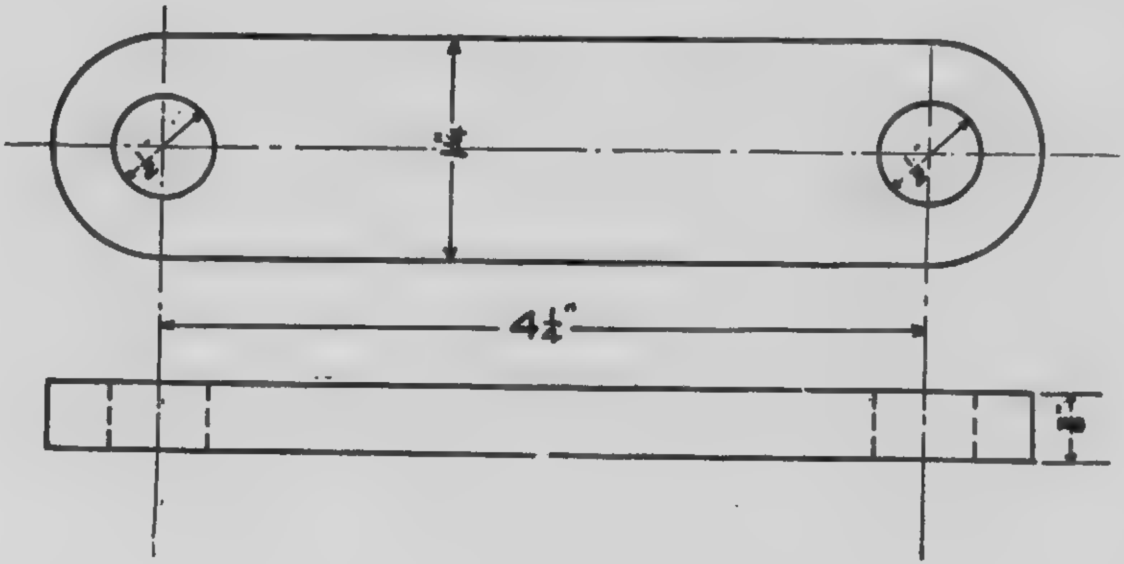
—NAMES AND PROPORTIONS OF STANDARD—
—RIVETS—
—IN RATIO TO THE DIAMETER—



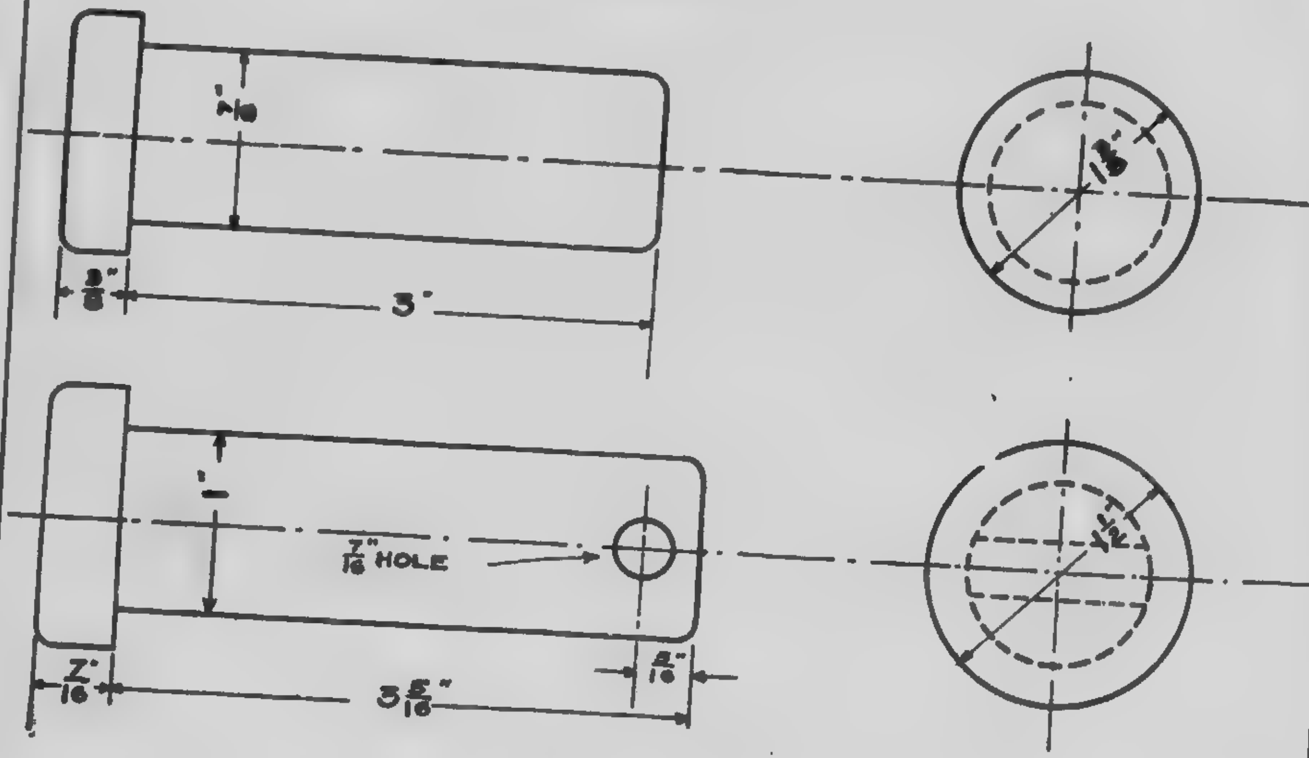
BOLT PROPORTIONS.

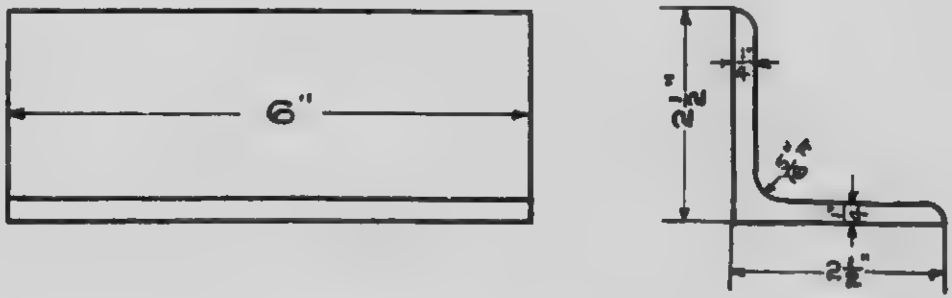
D = DIAMETER.

IRON STRAP



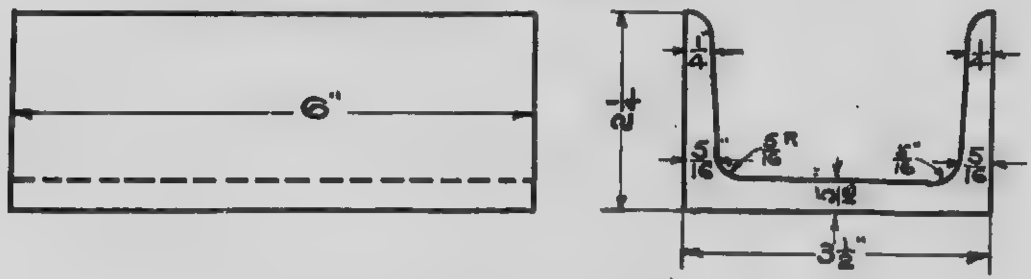
BRAKE PINS





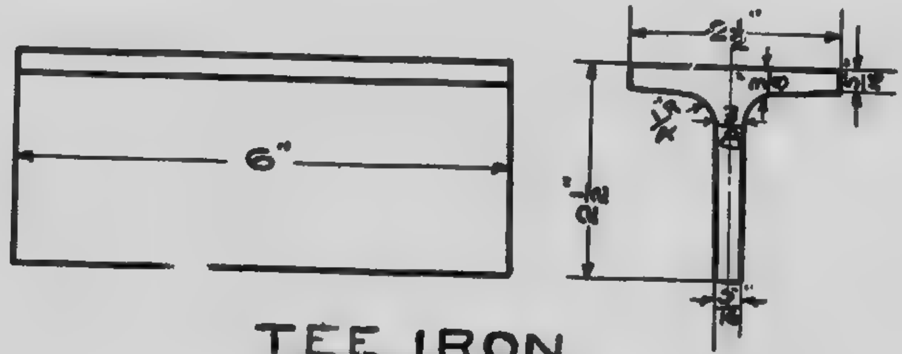
ANGLE IRON

DRAW FULL SIZE



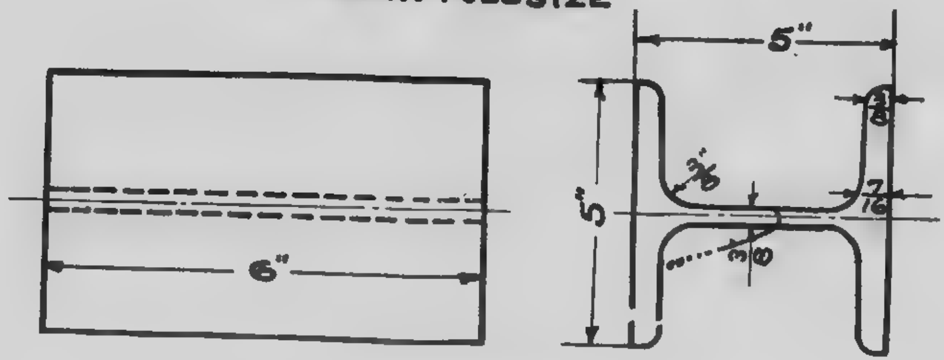
CHANNEL IRON

DRAW FULL SIZE



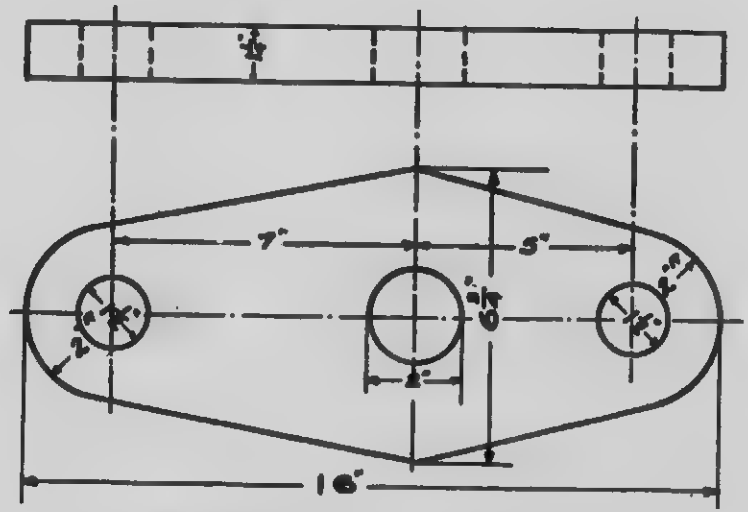
TEE IRON

DRAW FULLSIZE



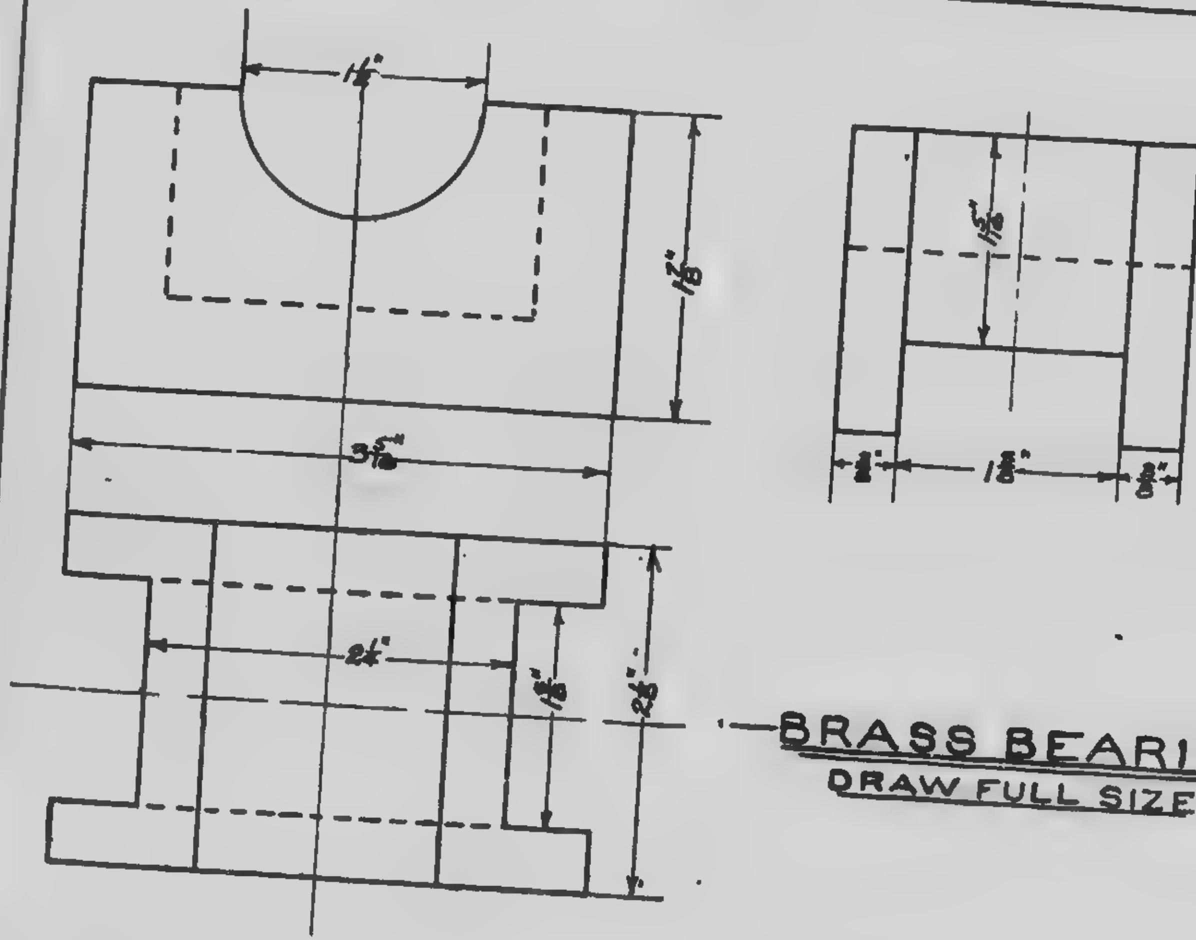
H. IRON

DRAW FULL SIZE



—BRAKE LEVER—

DRAW HALF SIZE

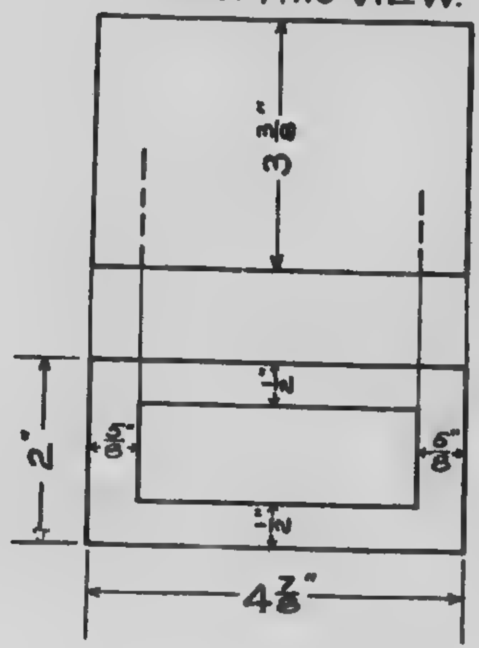


BRASS BEARING

DRAW FULL SIZE

MILLING JIG

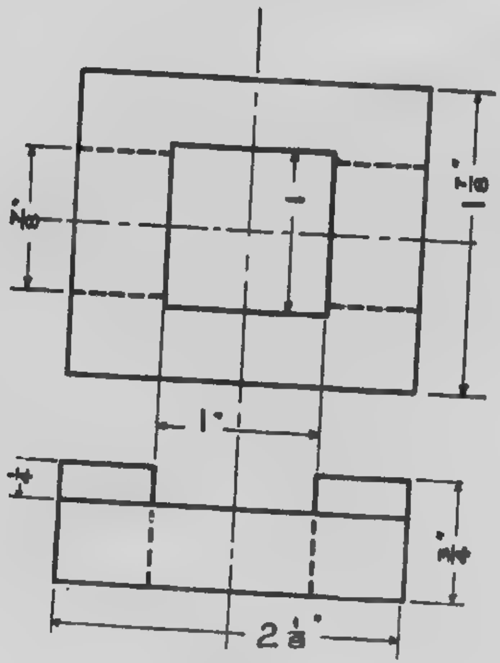
FINISH THIS VIEW.



DRAW END VIEW HERE.

DRAW FULL SIZE

ANCHOR FITTING

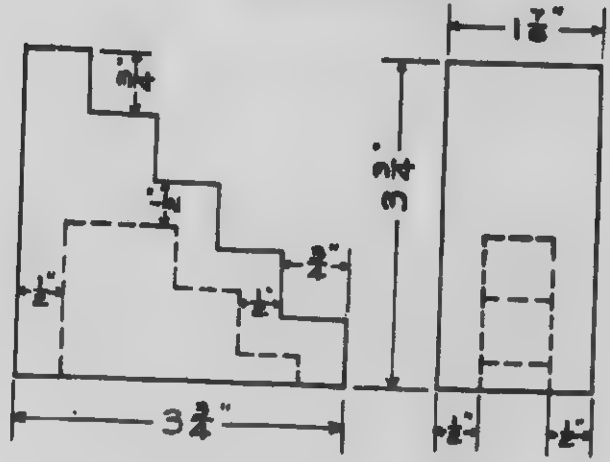


DRAW END VIEW HERE

DRAW FULL SIZE

CLAMP FITTING

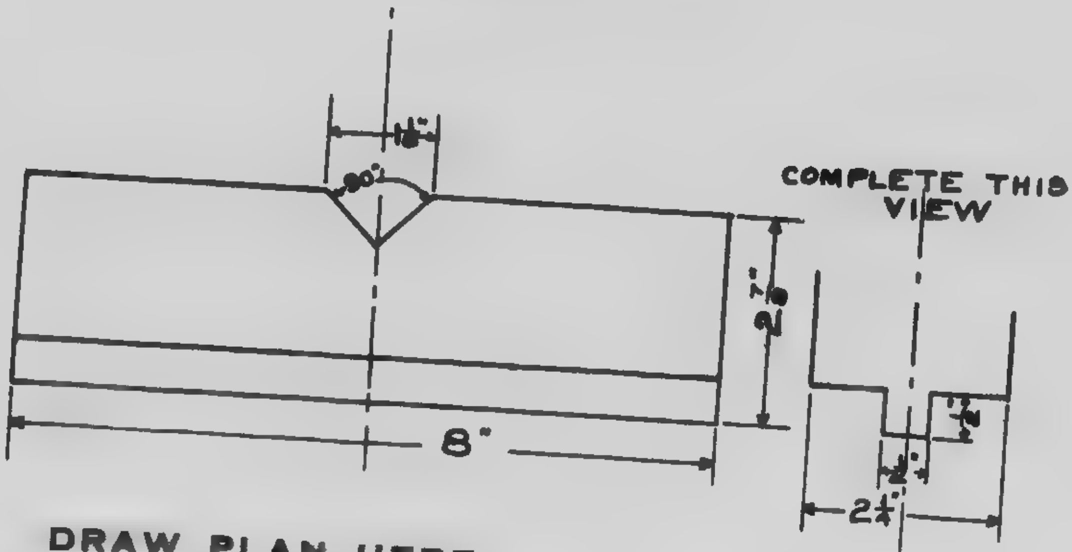
COMPLETE END VIEW.



DRAW PLAN HERE.

DRAW FULL SIZE

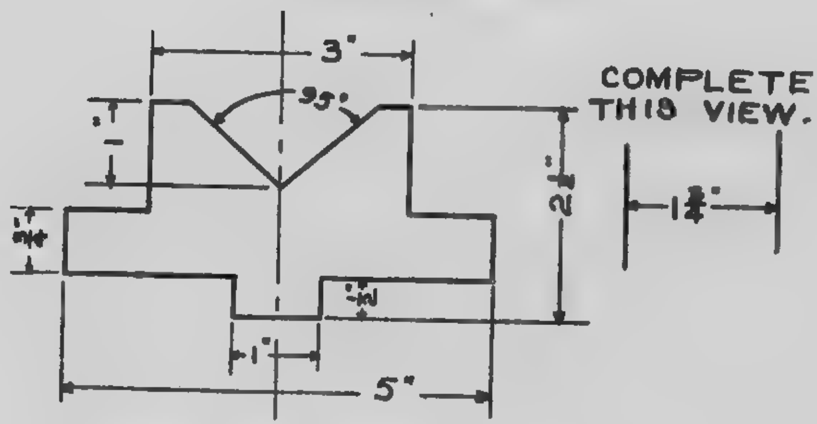
PLANER BLOCK



DRAW PLAN HERE

DRAW FULL SIZE

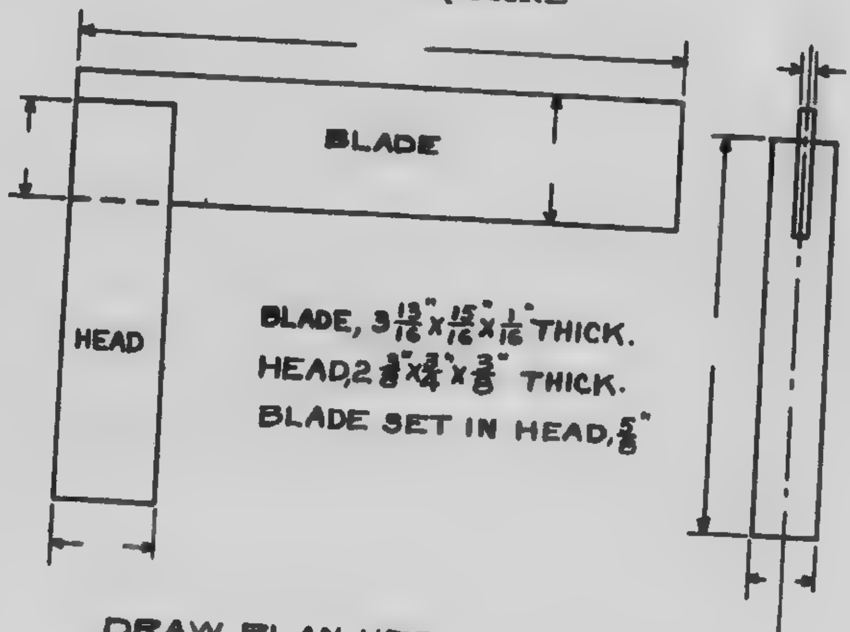
PLANER BLOCK



DRAW PLAN HERE.

DRAW FULL SIZE

TRY SQUARE

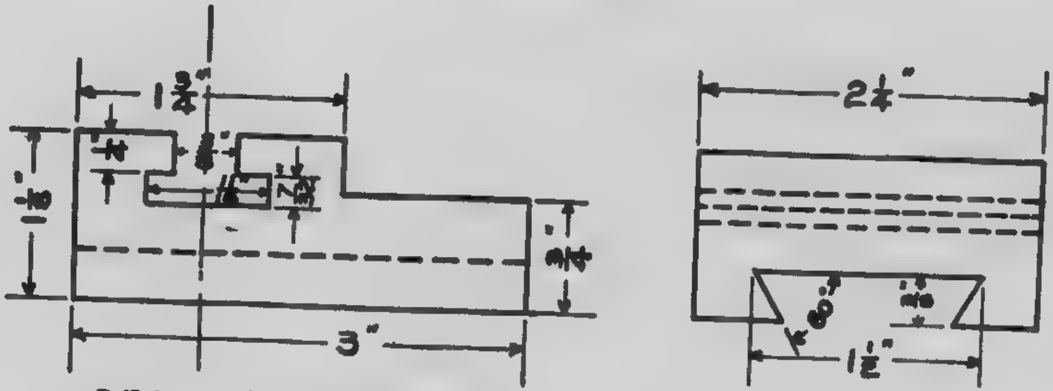


BLADE, $3\frac{13}{16}$" x $\frac{15}{16}$" x $\frac{1}{16}$" THICK.
HEAD, $2\frac{3}{8}$" x $\frac{3}{4}$" x $\frac{3}{8}$" THICK.
BLADE SET IN HEAD, $\frac{5}{8}$"

DRAW PLAN HERE.

DRAW FULL SIZE

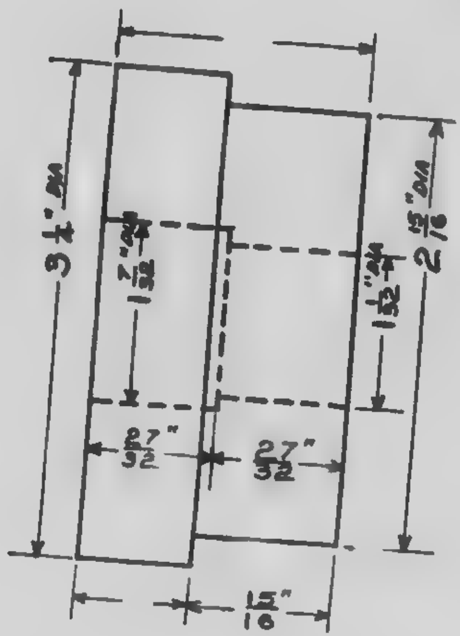
TOOL POST SLIDE



DRAW PLAN HERE

DRAW FULL SIZE

BUSHING



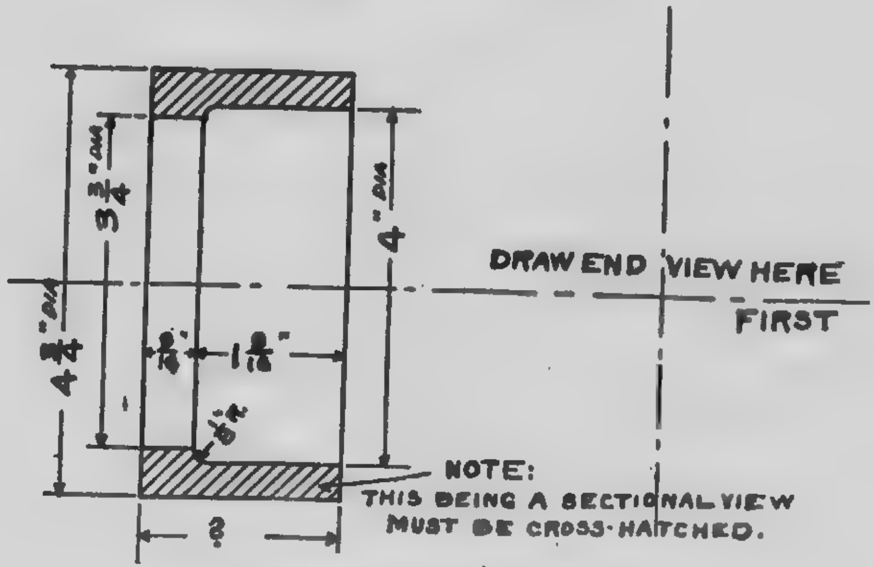
DRAW CENTER LINES.

DRAW ENDVIEW HERE.

SUPPLY MISSING DIMENSIONS.

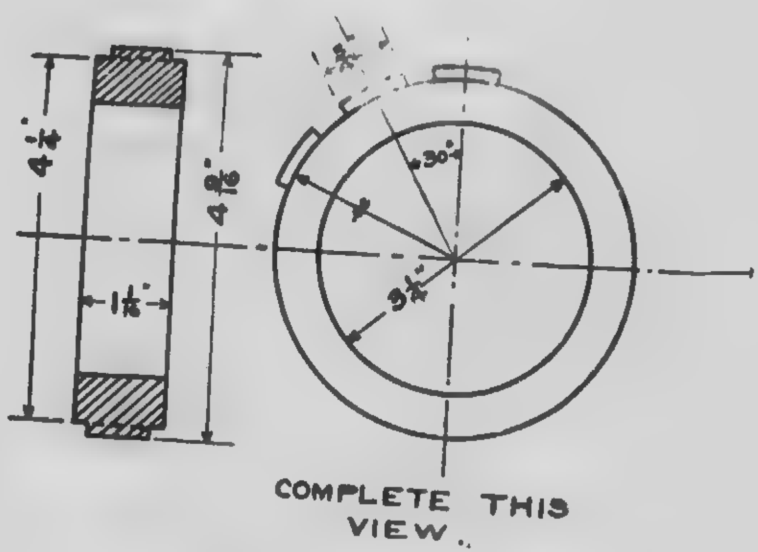
DRAW FULL SIZE

VIBRATING CUP



DRAW FULL SIZE

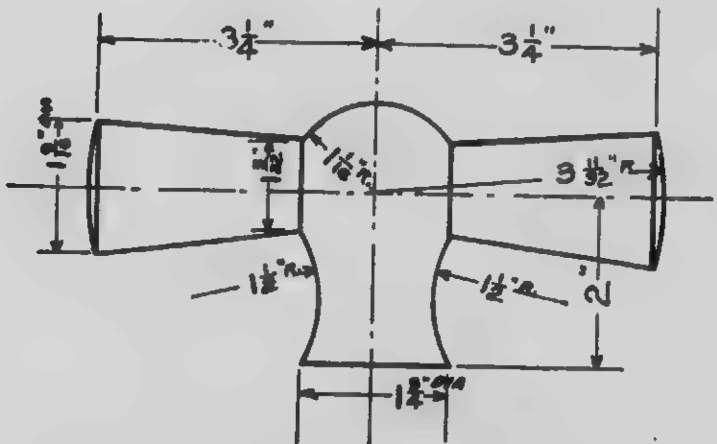
UNION NUT



DRAW FULL SIZE

CAST-IRON HANDLE

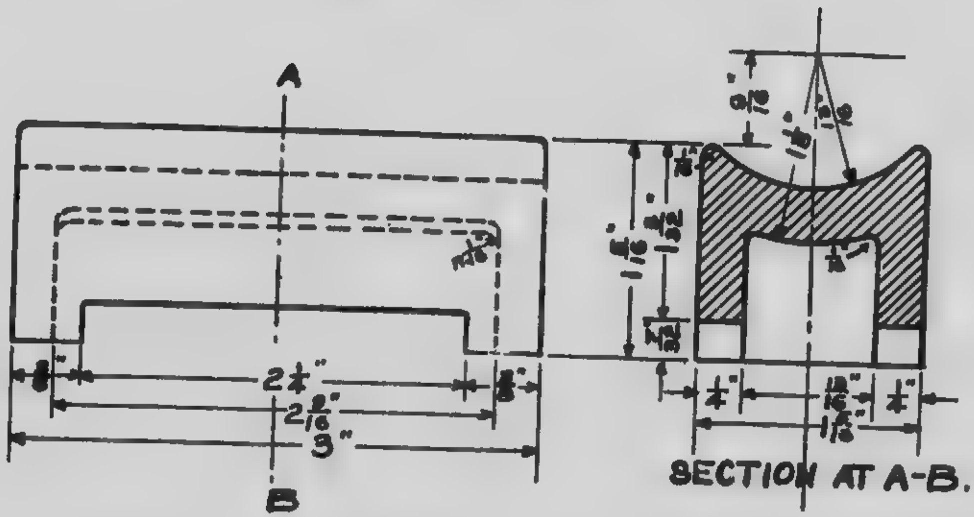
DRAW TO A SCALE OF 3 IN. = 1 FT.



DRAW END VIEW HERE

DRAW PLAN HERE

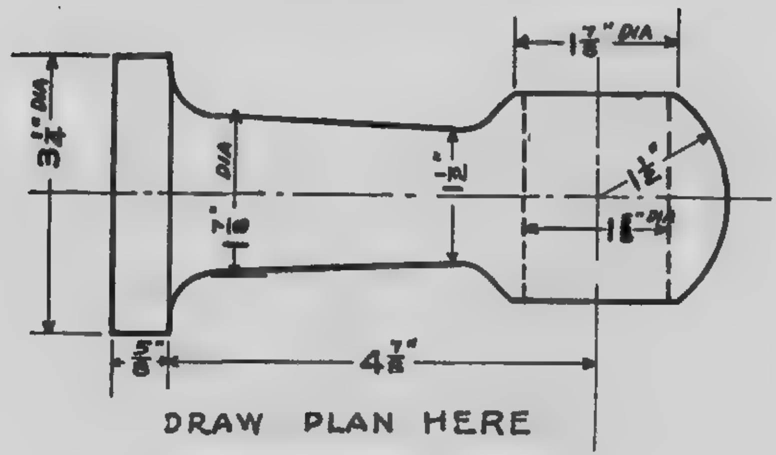
SHAFT SUPPORT



DRAW PLAN HERE

DRAW FULL SIZE

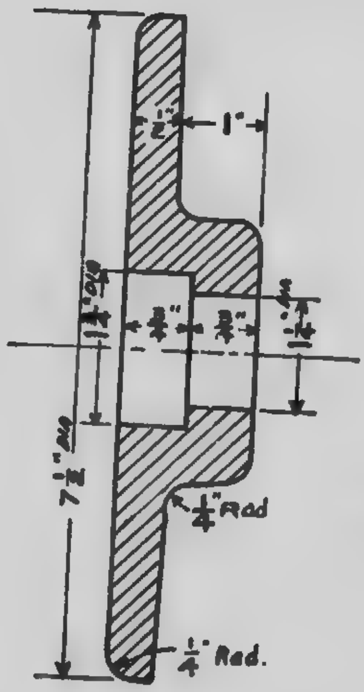
HAND RAIL COLUMN



DRAW PLAN HERE

DRAW FULL SIZE

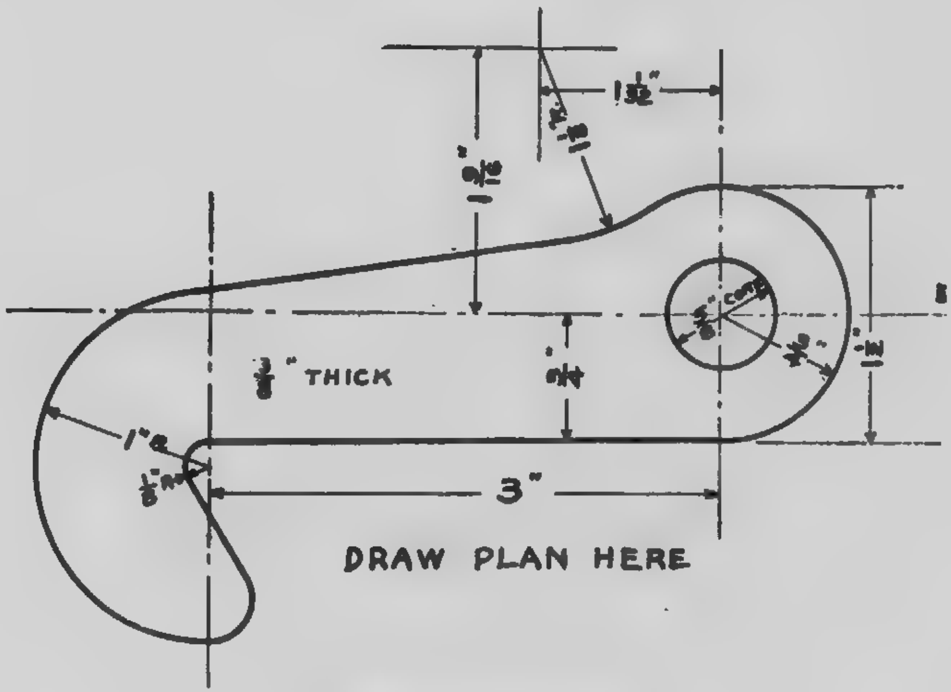
CRANK PIN COLLAR



DRAW VIEW HERE.

DRAW FULL SIZE

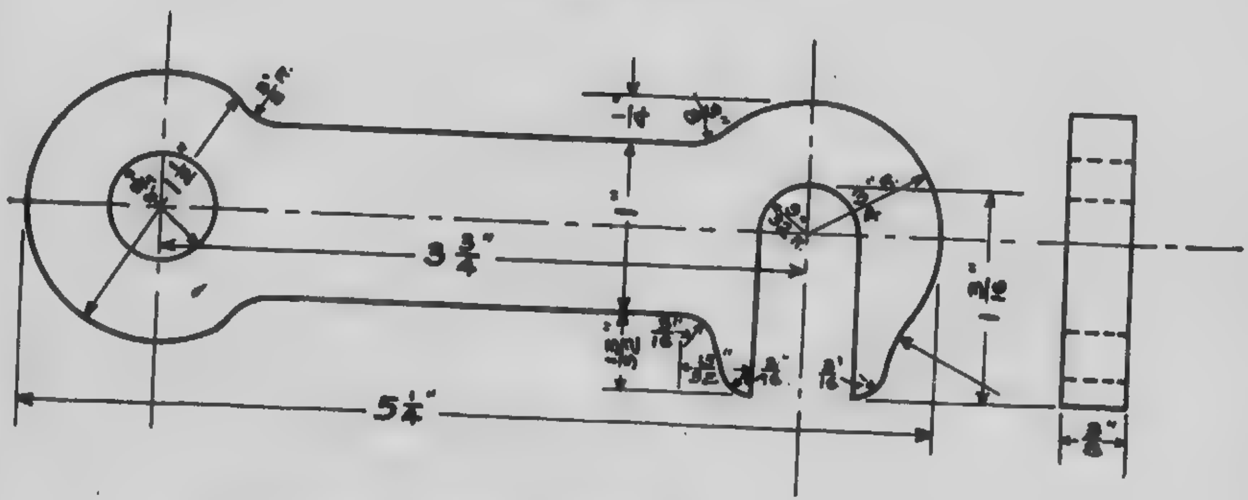
DOOR HOOK



DRAW PLAN HERE

DRAW FULL SIZE

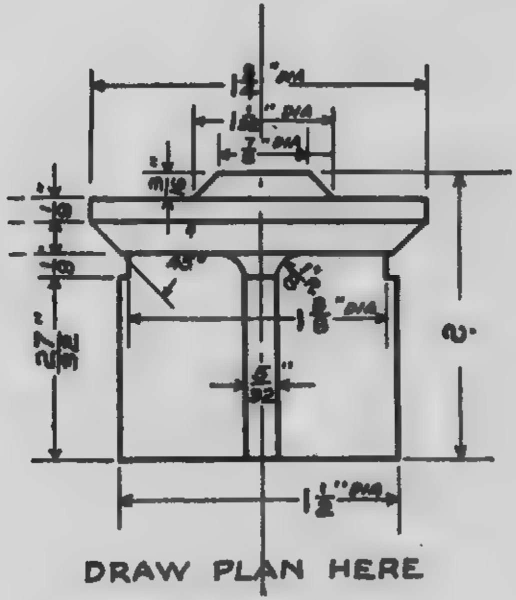
DOOR HASP



DRAW PLAN HERE

DRAW FULL SIZE

AIR VALVE



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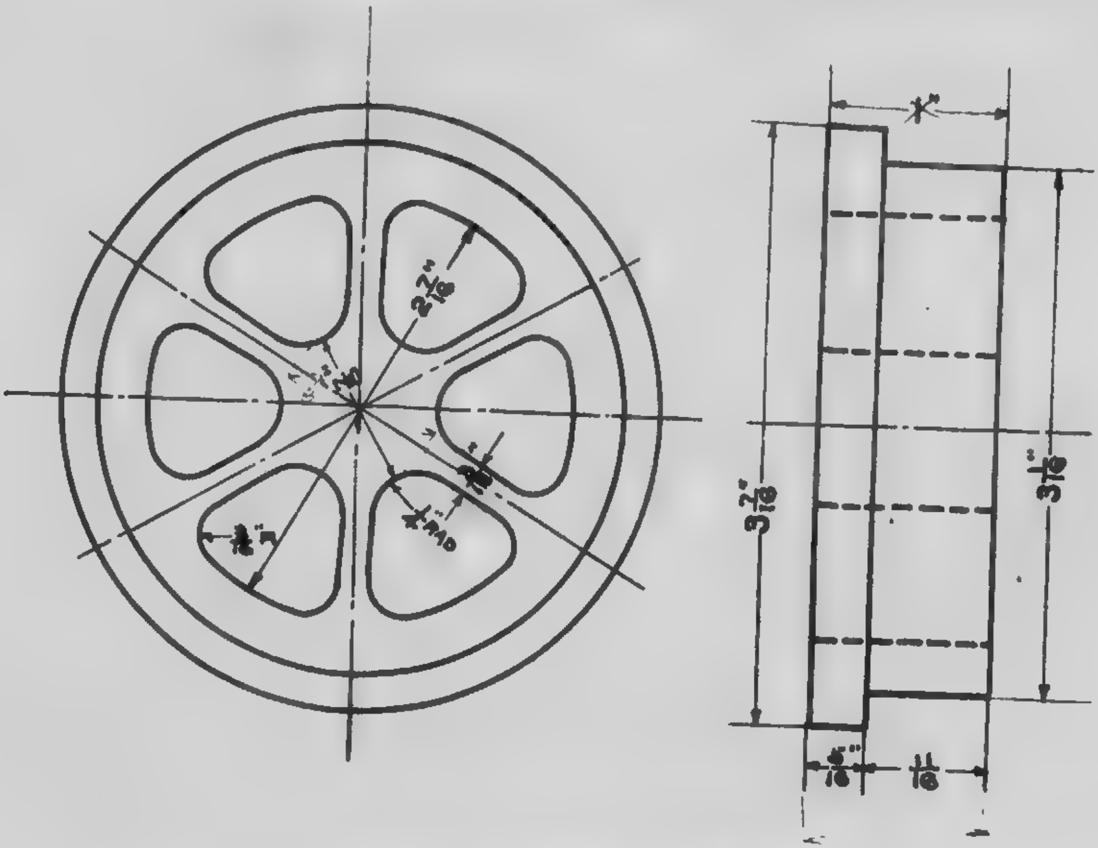
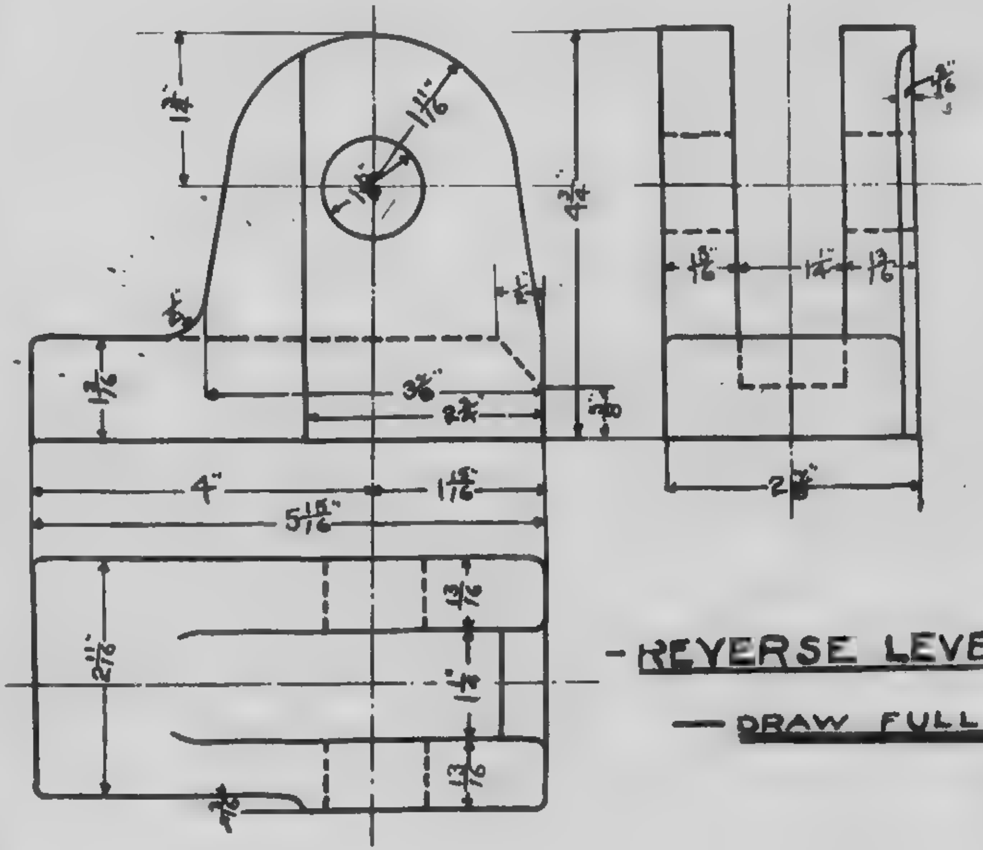
DRAW FULL SIZE



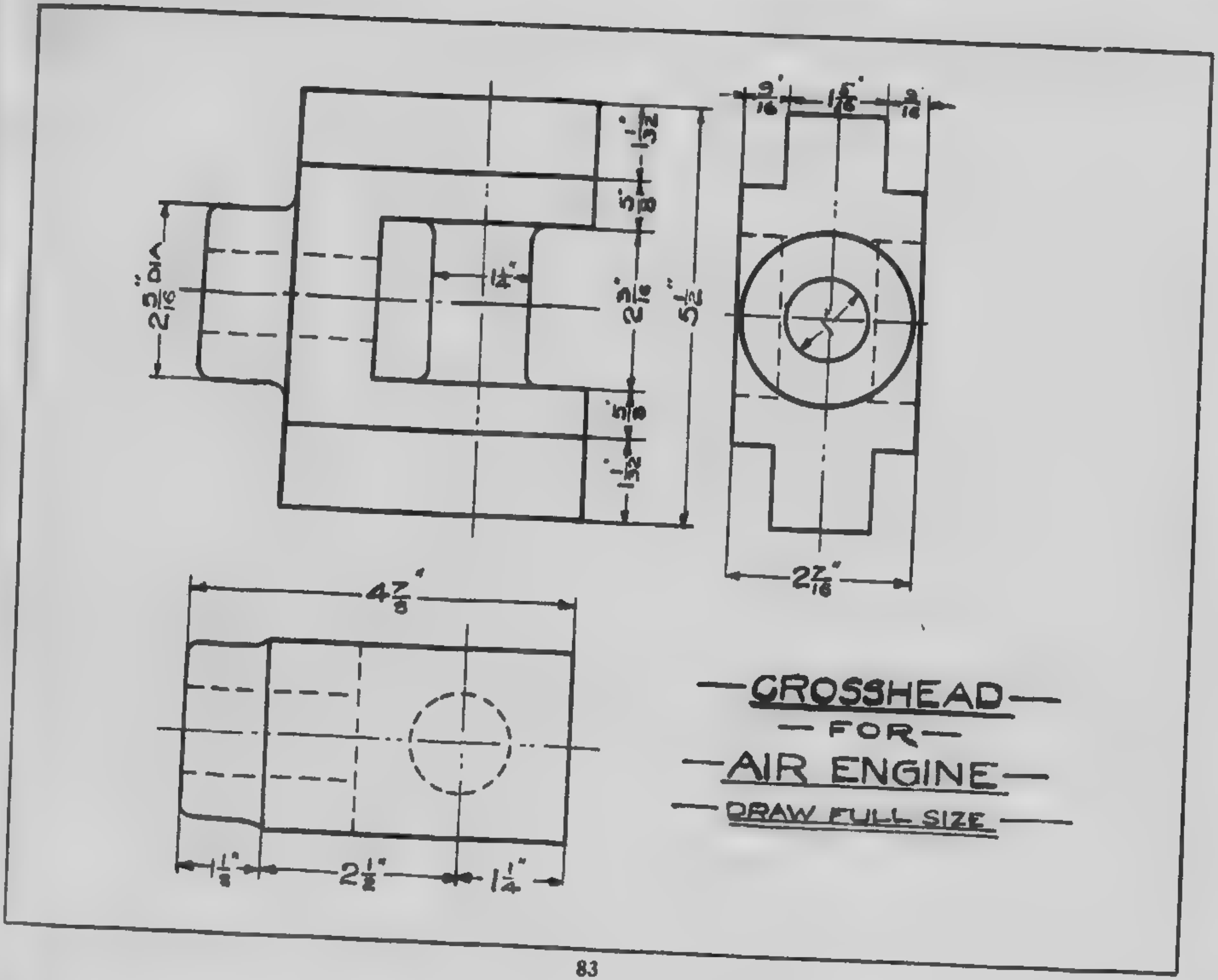
PUMP VALVE SEAT

DRAW FULL SIZE



- REVERSE LEVER BRACKET -

— DRAW FULL SIZE —



CROSSHEAD
FOR
AIR ENGINE
DRAW FULL SIZE

PROPER WAY TO REPRESENT A NUT

Very small nuts are most easily represented by a simple hexagonal prism. Generally, however, the effect of the "chamfer" can be easily represented, and it should be done to improve the appearance of the drawing. Fig. 29 shows the method of representing precisely the effect of turning off to a spherical form at the end.

Locate the point "c" as shown in figure. The front face of the prism cuts from the sphere (indicated by the dotted arc "alne"), a small circle of which the arc "bld," with centre at c, will be visible, and since this face is parallel to the paper, this arc will be seen in its true form.

Equal circles will also be cut from the sphere by the other visible sides, but since they are inclined to the paper, the arcs "akd" and "dme" will become part of ellipses and not true arcs on the paper.

An examination of Fig. 29 will reveal small spaces "aik" and "mne." These are not as a rule put on the ordinary representation of a nut.

Thus it will be seen that the shorthand representation adapted in most drawing offices, Fig. 29, No. 84, differs from the exact construction only in the omission of the portions "aik," "enm," and the use of two arcs of a true circle instead of the two elliptical portions.

These trifling differences between the two methods of representation effect a material saving of time and trouble, especially where the operation must be repeated several times.

The above discussion likewise applies to hexagon bolt heads.

Note.—All bolts have their various sizes proportional to their diameters. The thickness of the nut is equal to the diameter of the bolt. The head of the bolt is generally the same thickness as the nut, but sometimes is made equal to ⅞ the diameter. The distance across flats of the hexagon is equal to 1½ times the diameter plus ⅛". The distance across corners of the hexagon is equal to twice the diameter. These sizes will be approximate, but will serve the purpose of our drawing.

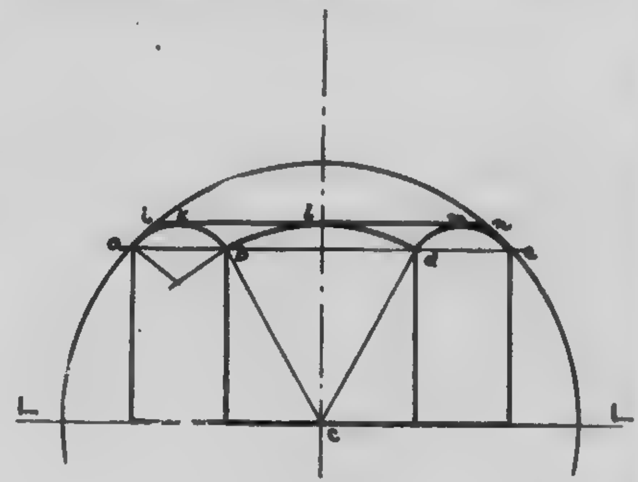


FIG. 29

SECTION OF STANDARD THREADS

The thread used on bolts commonly met with in different kinds of machinery is known as the United States Standard. Near the end of this book you will find tables giving the pitch of the thread (number per inch) for bolts of various diameters. Fig. No. 30 shows a cross-section of the thread and indicates the proportions and angles used in its formation. This thread is standard for all ordinary machine work, bolts, cap screws, studs, and other machine details. It is not, however, the one used for pipe work and boiler work, the difference being that in the two last-named classes of work the sharp V-thread is used, whereas the U.S. Standard is slightly flattened on top and correspondingly in the groove.

The exact drawing of a thread is a difficult part of mechanical drawing, and it is not usual to show the exact form of each individual thread unless there is a very special reason, as this would be a waste of time for which there would be no valid excuse.

In the conventional methods used to represent threads, some of them show a sectional shape, but for convenience in drawing the U.S. Standard threads the slight "flattening" referred to above is left off and a sharp V-thread section used instead. You will notice in Fig. 30 that the characteristic angle is 60°, both for the solid part of the thread and the groove, this making the sections a series of equilateral triangles.

For practice, copy Fig. 30 several times, using a different dimension each time for the pitch. By using the T-square and 60° triangle the depth is determined mechanically. If desired to calculate the depth it can be obtained by multiplying the pitch by .866. The amount of "flat" on the thread is equal to one-eighth of the pitch.

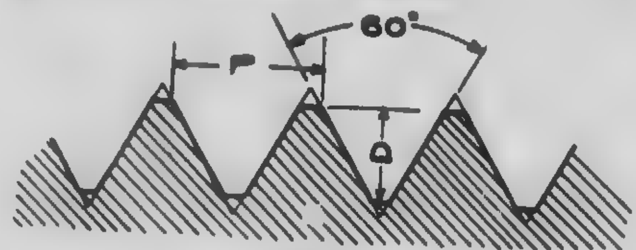
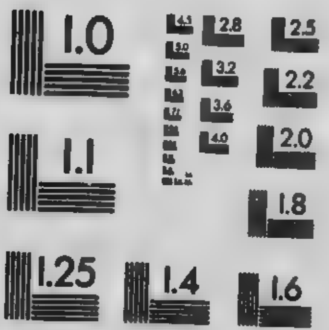


FIG. 30

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



DRAWING SCREW THREADS

A good practical method of indicating the screw thread is shown in Fig. 31. Instead of drawing the actual V-shape of the threads they are merely indicated by a series of parallel lines, alternately long and short, properly inclined, as required by the pitch. The inclination can readily be determined, as shown in the right-hand part of the figure, by using the 60° triangle to draw the section of a single thread, then, since the root on one side of the bolt is opposite the crest on the other side, "ca" is drawn "square across," and b. a. at the desired inclination. This inclination is transferred to the drawing of the bolt by using the triangle.

This is a purely conventional way of indicating a screw thread; it is not, and does not pretend to be, a "drawing" of it in any proper sense; but it answers the purpose just as well as the most accurate detailed drawing. This is especially true in the case of small bolts, where even the most painful accuracy in the use of the instruments fails to give a look of neatness and uniformity to the drawing.

If the bolt is very large, the above rules of representing it in a full-size drawing are not eligible. It is, however, very rarely that one is used of such dimensions as to make it worth while to construct an **exact projection** of it, introducing all the details of the flattening of the crest at the top and the groove at the bottom, the helical curves of the thread, etc. As a compromise between this and the preceding processes, that shown in Fig. 33 may be used with good effect.

This process consists in laying out the section of a full, sharp V-threaded screw, which is carefully drawn with the 60° triangle, after which the tops of the threads are joined by one series of parallels and the bottoms by another series, drawn heavier, which, of course, have a slightly different inclination.

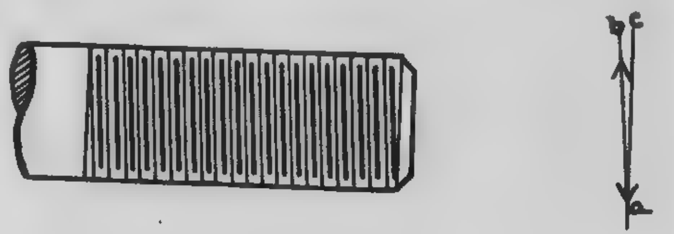
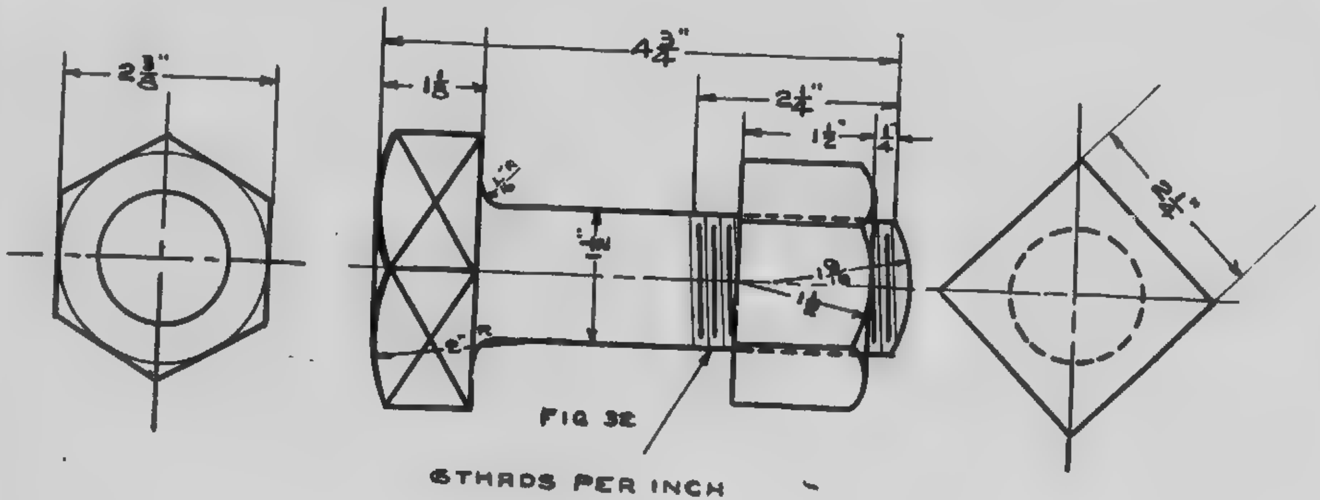


FIG. 31

In setting off the pitch or number of threads per inch, mark off directly from the scale with your pencil and do not make use of the dividers. There are two very good reasons for this—one being that the slightest error in the setting of the dividers is multiplied as you space along a given distance; the other reason is the bad appearance given the sheet by the pinholes from the dividers, especially if a mistake has to be corrected. The use of the 60° triangle will give the required depth to the thread, but, as an aid to uniform appearance, run two light parallel lines along, the distance between which will represent the root diameter of the thread.

It will be necessary to have your pencils in the best of shape before attempting to draw threads of any description.



— BOLT AND NUT —

DRAW FULL SIZE

FIG. 77

1¼" BOLT

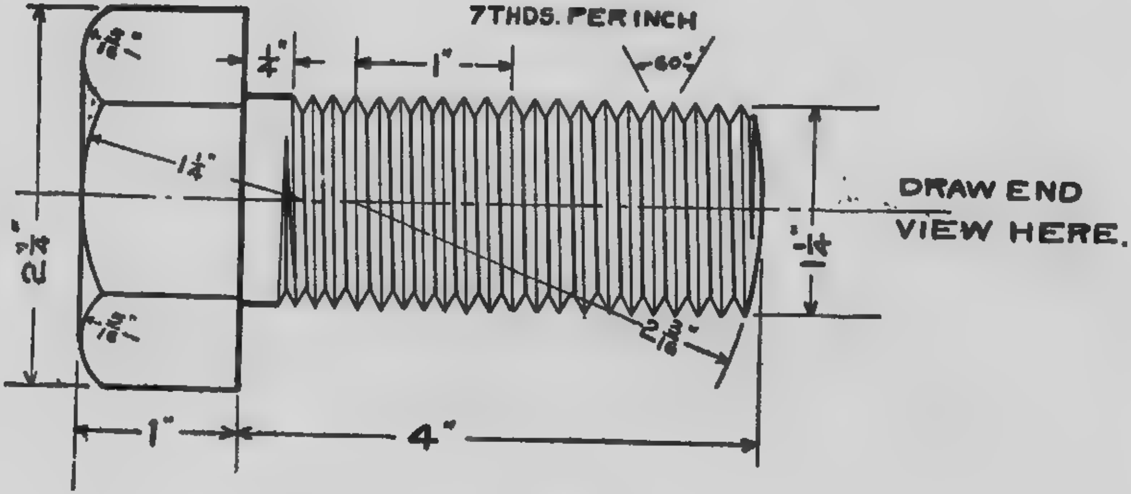


FIG. 33

DRAW FULL SIZE

DRAWING TO SCALE

Working drawings are preferably and usually made "full size," unless they would thereby be either too large or too small to be conveniently worked from. In that case they must be made upon a smaller or larger scale; that is to say, an inch must be represented by a distance less or greater than an actual inch, and its multiples or submultiples are, of course, reduced or enlarged in the same proportion.

To aid us in drawing to scale we make use of an instrument called a "scale rule." Now, reduced or enlarged drawings can be made with the aid of only the scale rule, the operation being very simple.

An ordinary rule may serve the purpose, as, for instance, a "quarter-size" drawing is wanted; each dimension of the object is divided by four, and the quotient set off with the full-size scale or a rule. It is easy enough to divide by four, but if done repeatedly, as would be required on a large drawing, the operation of mental arithmetic would become monotonous. And this repetition can be wholly avoided by the simple expedient of using the "scale rule," reading the dimensions directly from it as if it were an ordinary rule. Once having decided which scale you will use for a drawing, be careful to see that all the dimensions are taken from that scale, or else the drawing will not be in proportion.

The quarter-size scale is formed by taking three inches to represent one foot, this three-inch space being divided into twelve equal parts, each one of which represents one inch; and these are subdivided, like the actual inch on a rule, into halves, fourths and eighths.

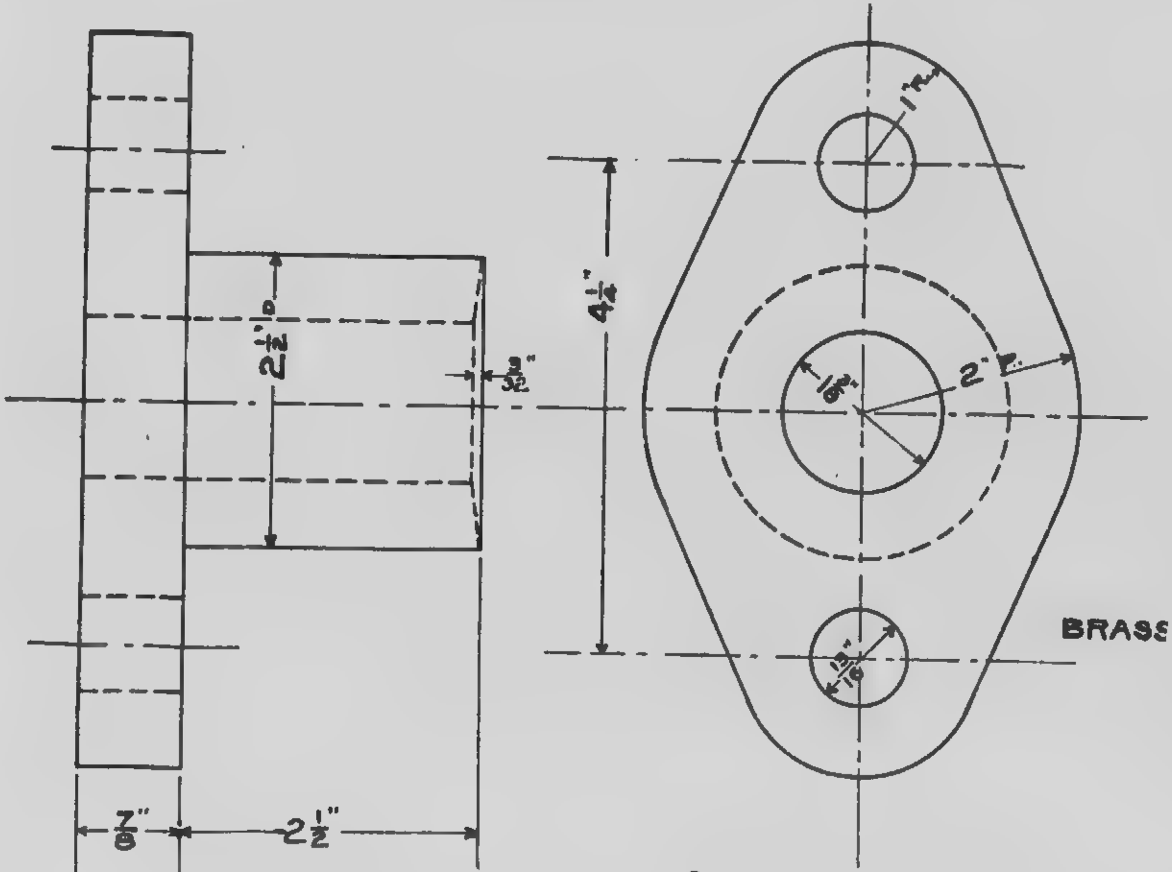
In like manner, **any** distance may be selected to represent a foot, and a similar scale constructed, by dividing it into twelve parts, and subdividing them as before. Such scales are usually designated by stating the distance taken to represent a foot; as for example, "3in. to the foot," "1½in. to the foot," "½in. to the foot," etc. These same scales are often referred to as the 3in. scale, the 1½in. scale, the ½in. scale, etc.

Notice that when 12in. equal a foot it is the "full size scale"; when 6in. equal a foot it is "scale one-half"; when 3in. equal a foot it is "scale one-quarter"; when 1½in. equal a foot it is "scale one-eighth," etc.

If a drawing was being made double size we refer to it as scale two.

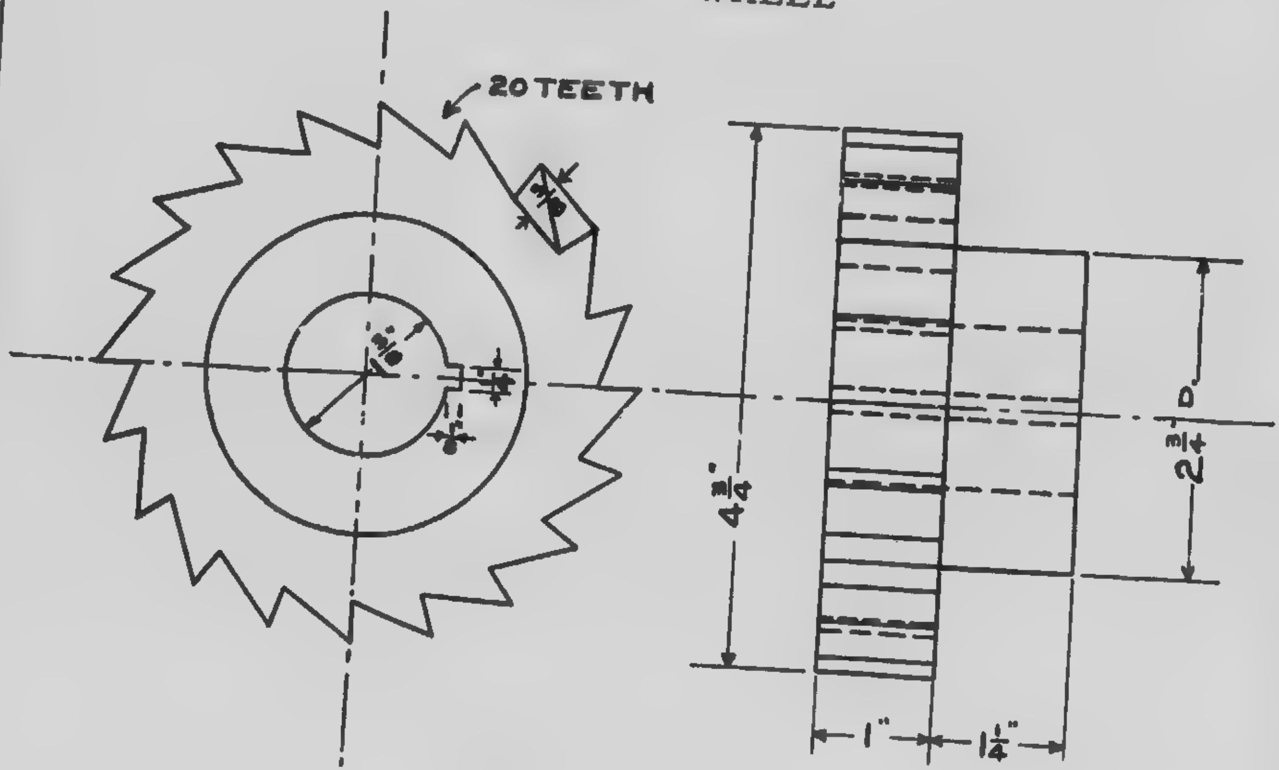
Choosing the scale to be used is a matter of judgment on the part of the draughtsman. The scale must be such that the drawing will show everything plainly and at the same time not too large.

PACKING GLAND



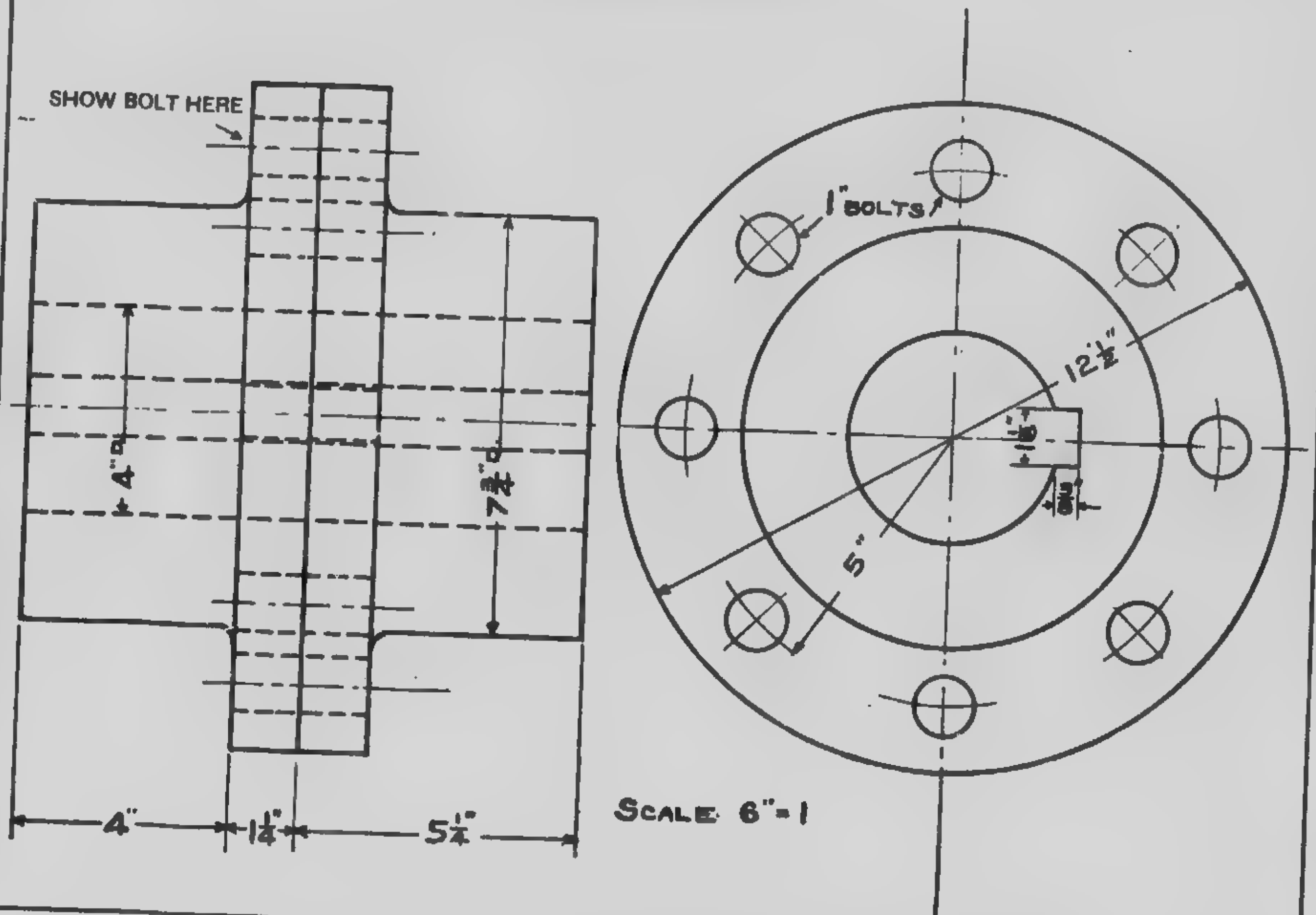
DRAW FULL SIZE.

RATCHET WHEEL

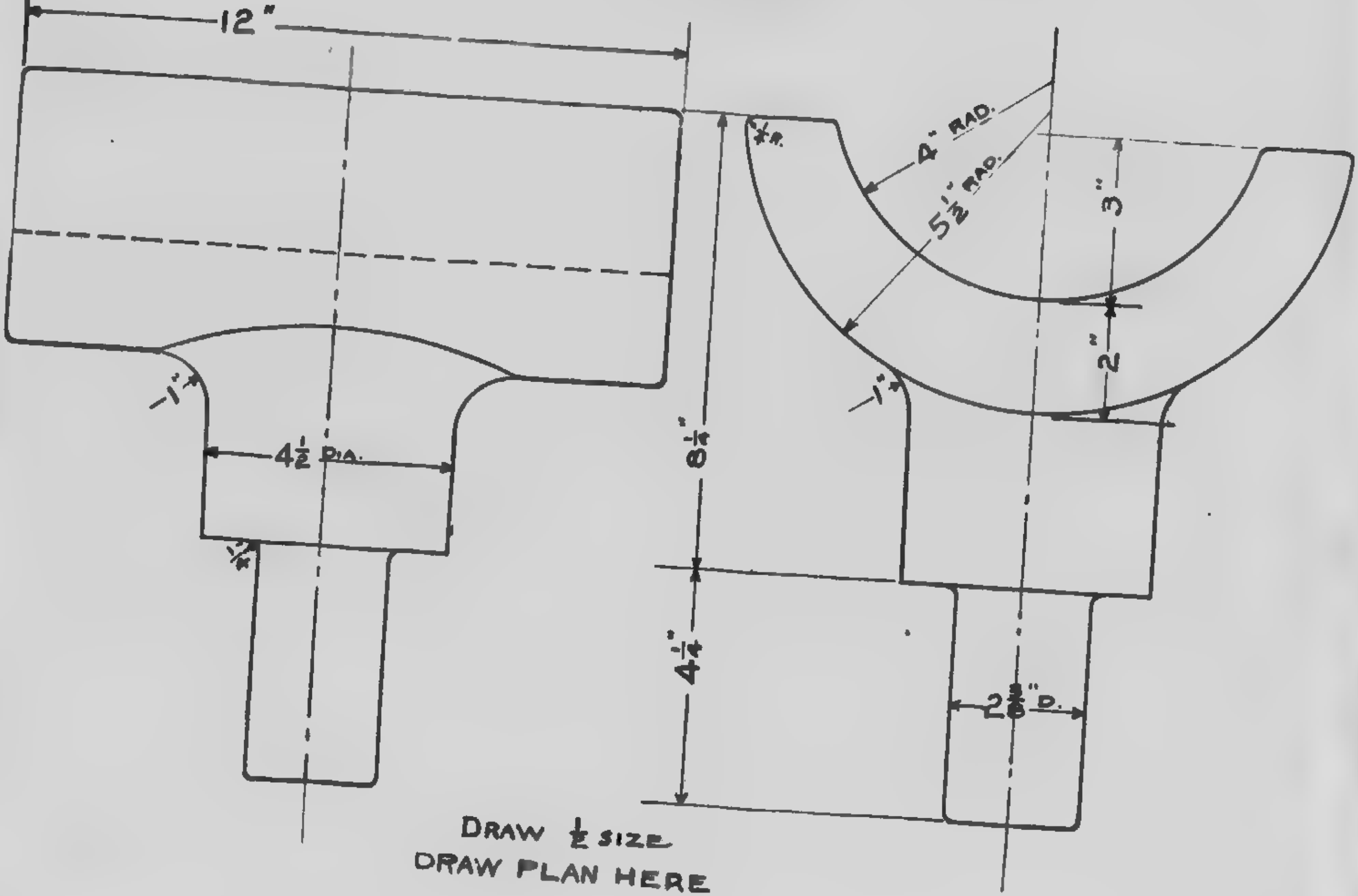


DRAW FULL SIZE.

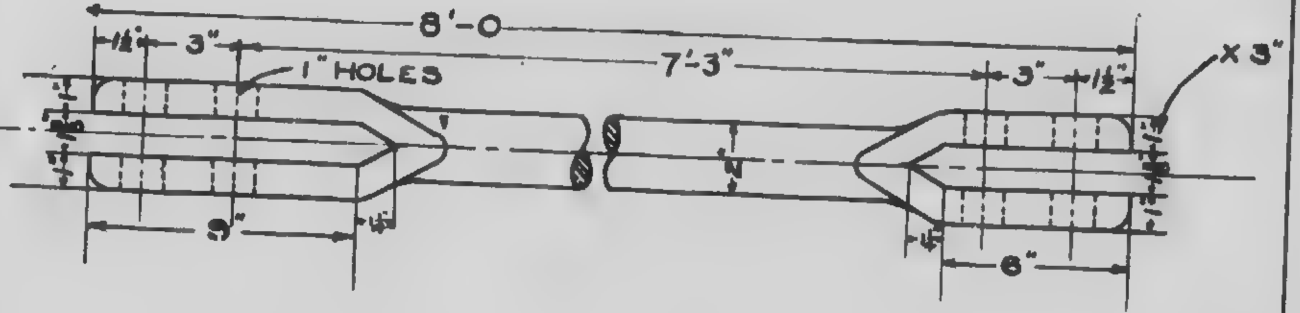
SHAFT COUPLING



JACK HEAD



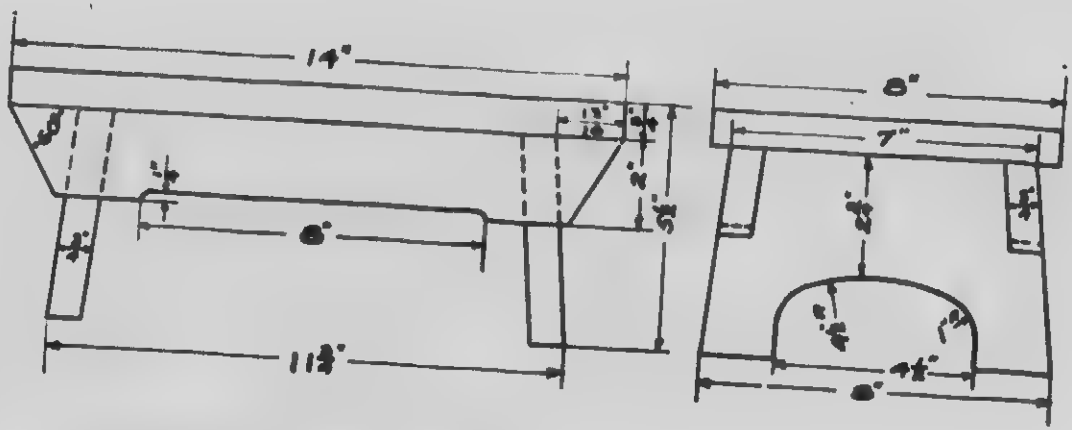
12"
1/8 R.
4" RAD.
5 1/2" RAD.
3"
2"
1"
4 1/2 DIA.
8 1/4"
4 1/4"
1/8
2 3/8" D.
DRAW 1/2 SIZE
DRAW PLAN HERE



DRAW PLAN HERE

BRAKE ROD

DRAW HALF SIZE

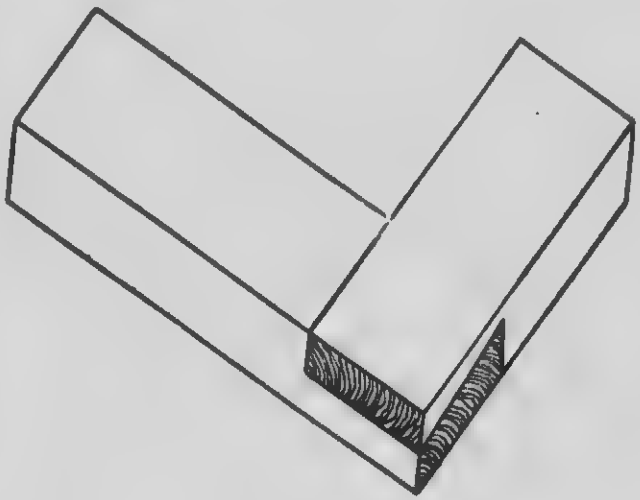


DRAW PLAN HERE

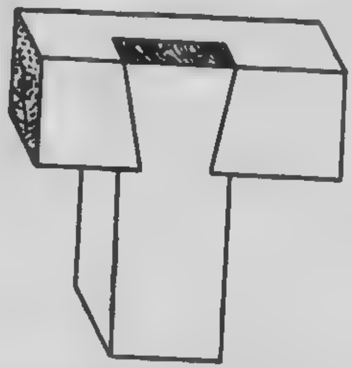
FOOTSTOOL

DRAW HALF SIZE

The following exercises are inserted here to acquaint the apprentice with isometric views of objects. The subjects illustrated are simple joints used in carpentry, and other mechanical objects.

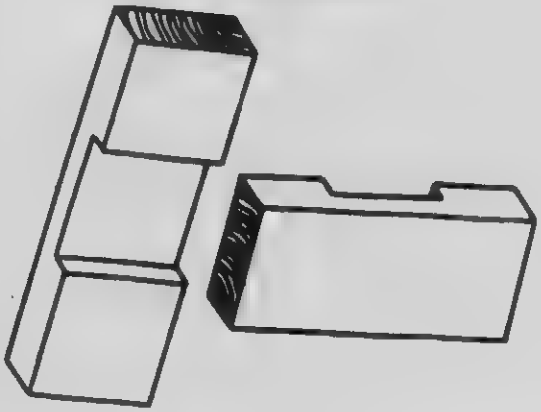


Bevelled Halved Joint



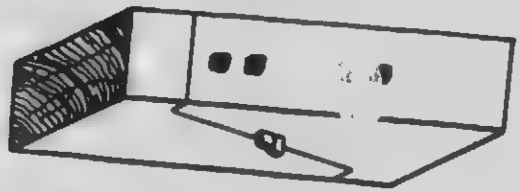
Draw the above figure about twice this size, and make another view showing pieces separate.

Dovetail Joint



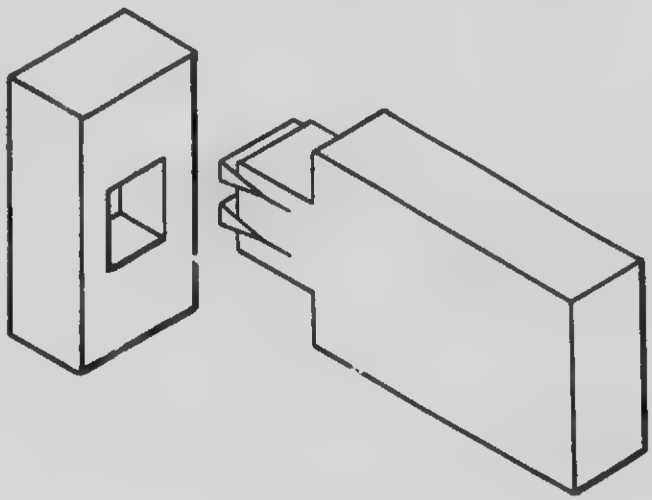
Draw the above figure as shown and make another view showing pieces assembled.

Notched Joint



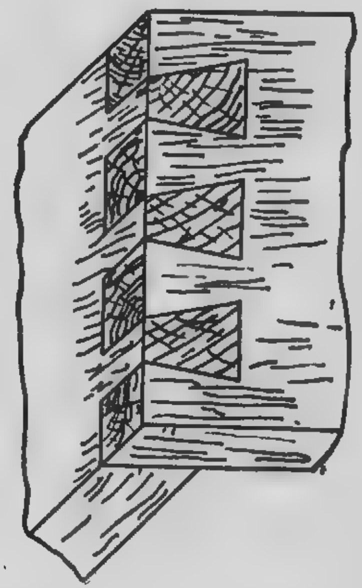
Draw the above figure about twice the size, and make another view showing pieces separate.

Scarf Joint



Draw the above figure as shown and make another view showing pieces assembled.

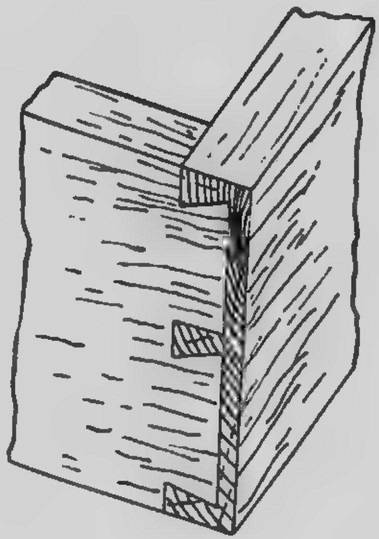
Wedged Joint



Draw the above figure about twice the size, and make another view showing pieces separate.

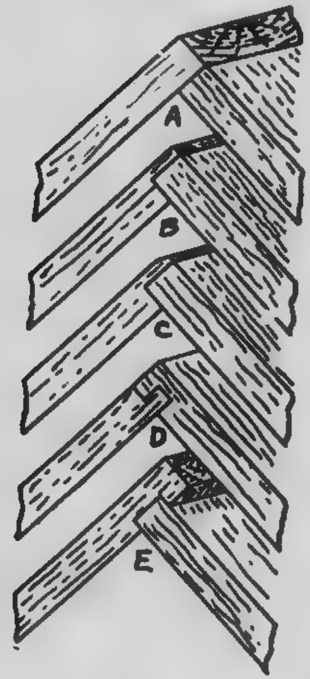
make

Dovetail Joint



Draw the above figure about this size, and make another view showing pieces separate.

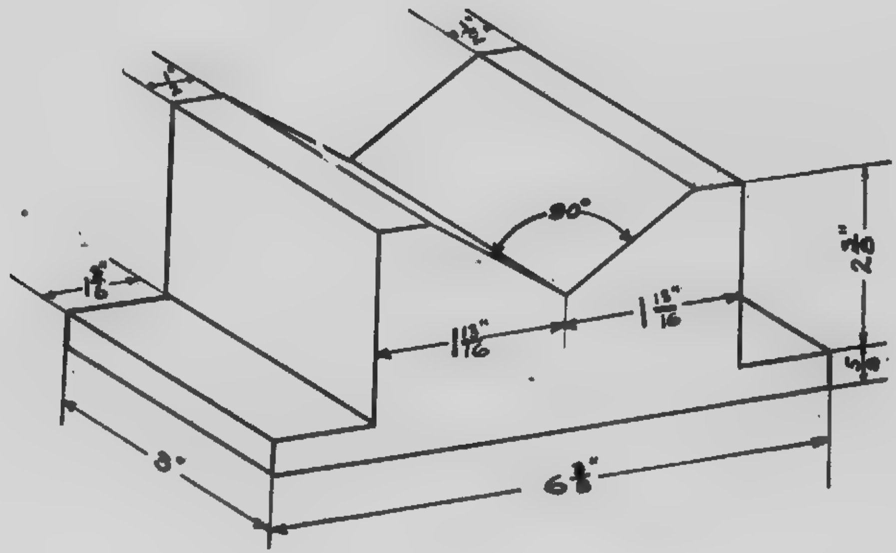
Drawer Dovetail Joint



Draw the above figure about twice this size, and make another view showing pieces separate.

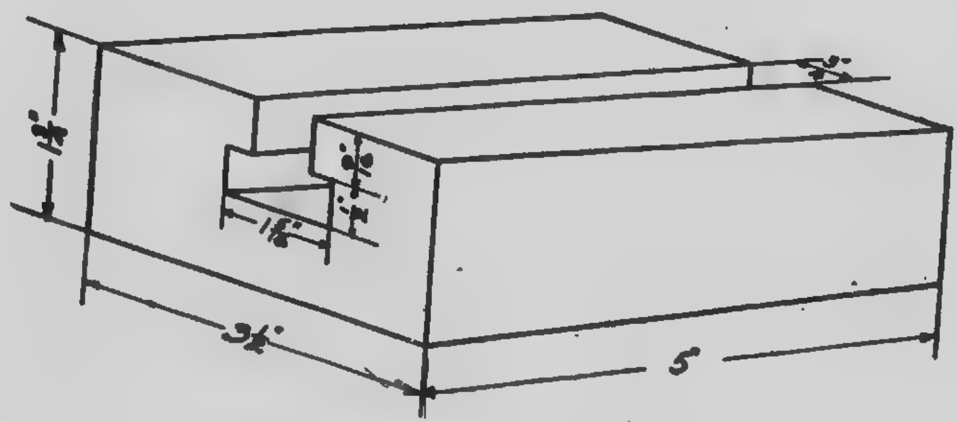
Exercise. Sketch views of each of the above types of joints in your sketch book, making each one about three times this size.

DRAW PLAN AND ELEVATION



V BLOCK

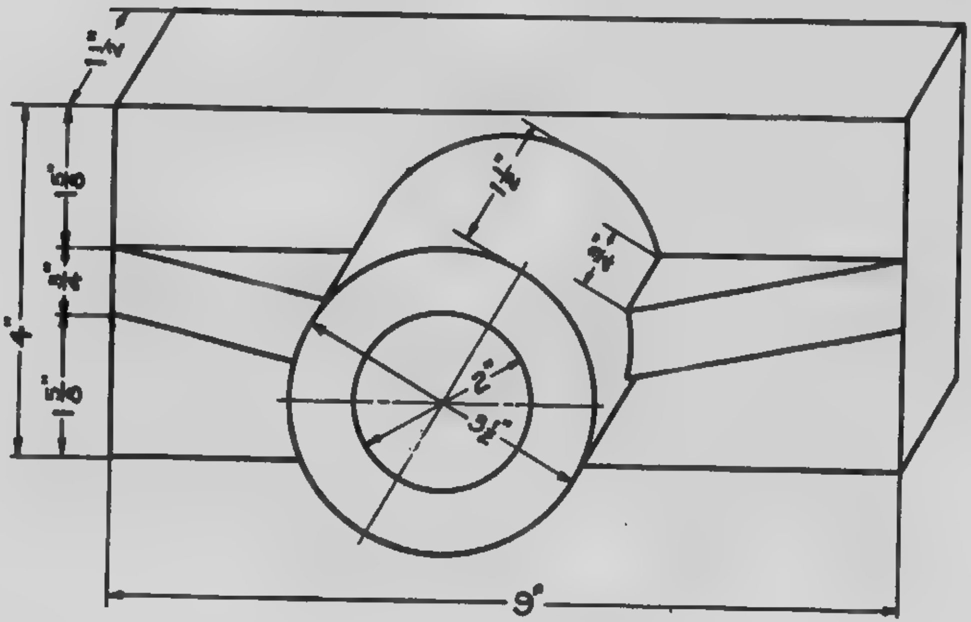
DRAW FULL SIZE



T SLOT PLATE

DRAW PLAN, ELEVATION AND END VIEW
FULL SIZE

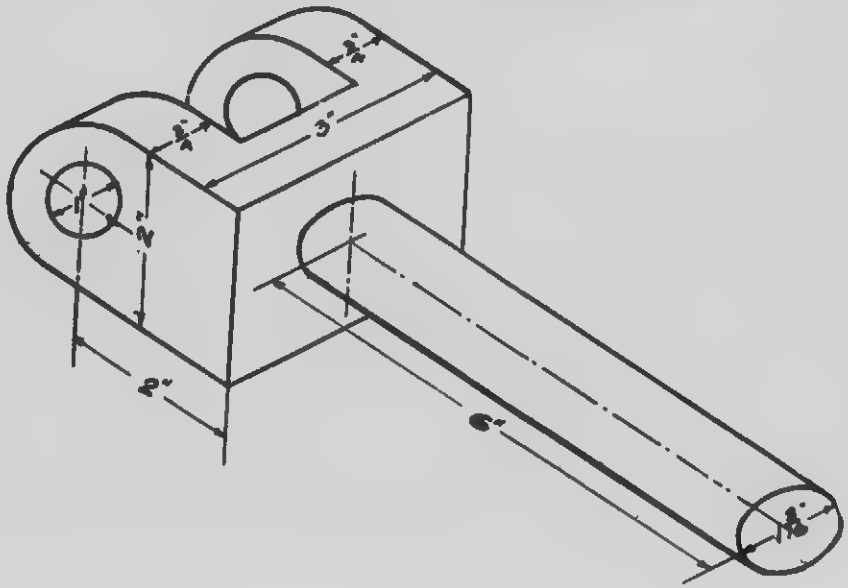
DRAW PLAN AND ELEVATION



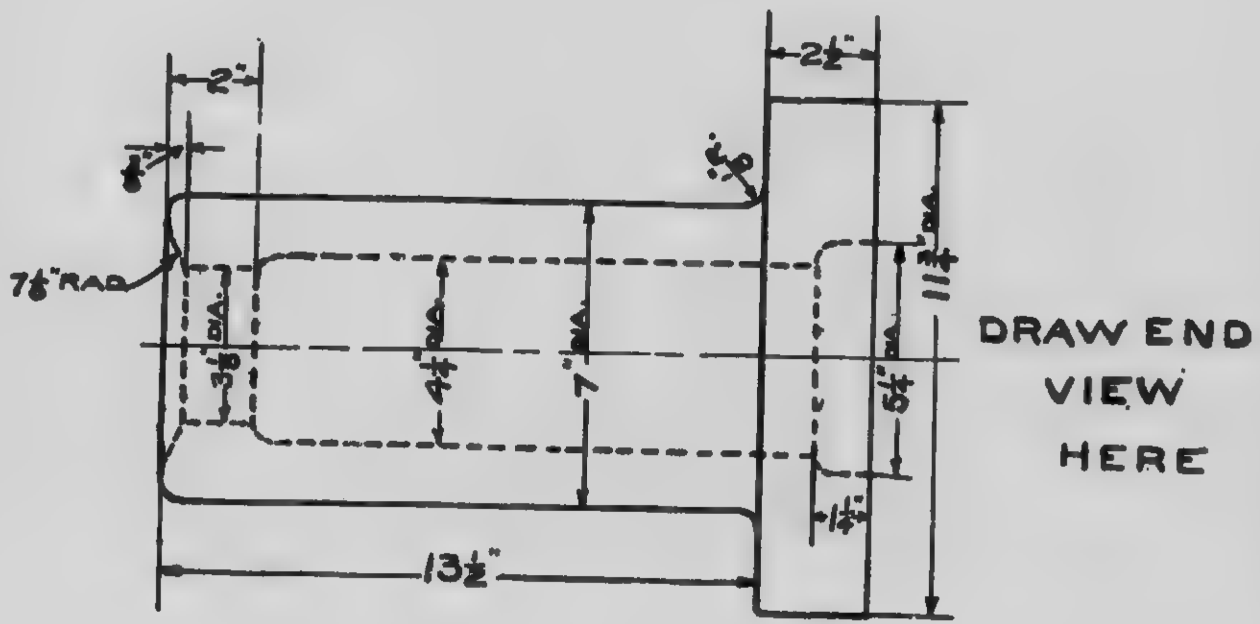
CAST IRON BRACKET

FULL SIZE

DRAW PLAN AND ELEVATION

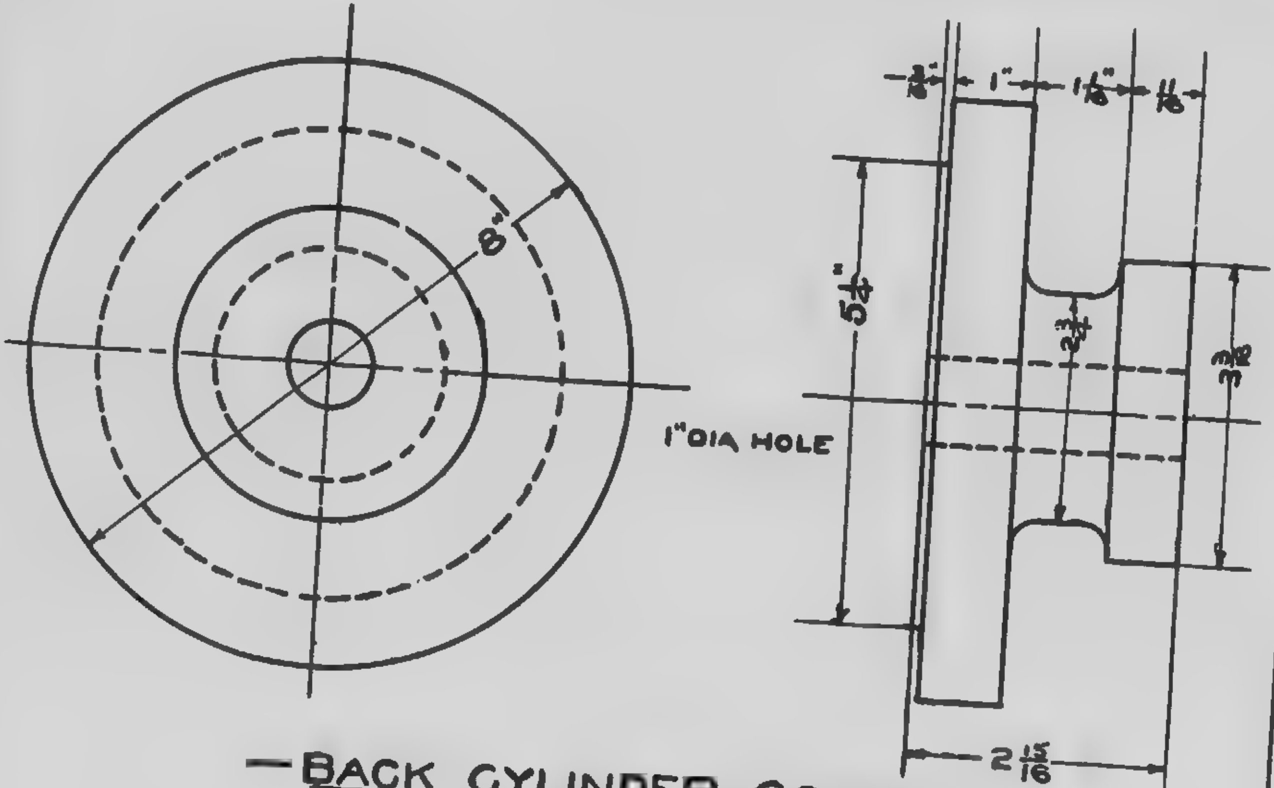


— WROUGHT IRON CLEVIS —
— DRAW HALF SIZE —

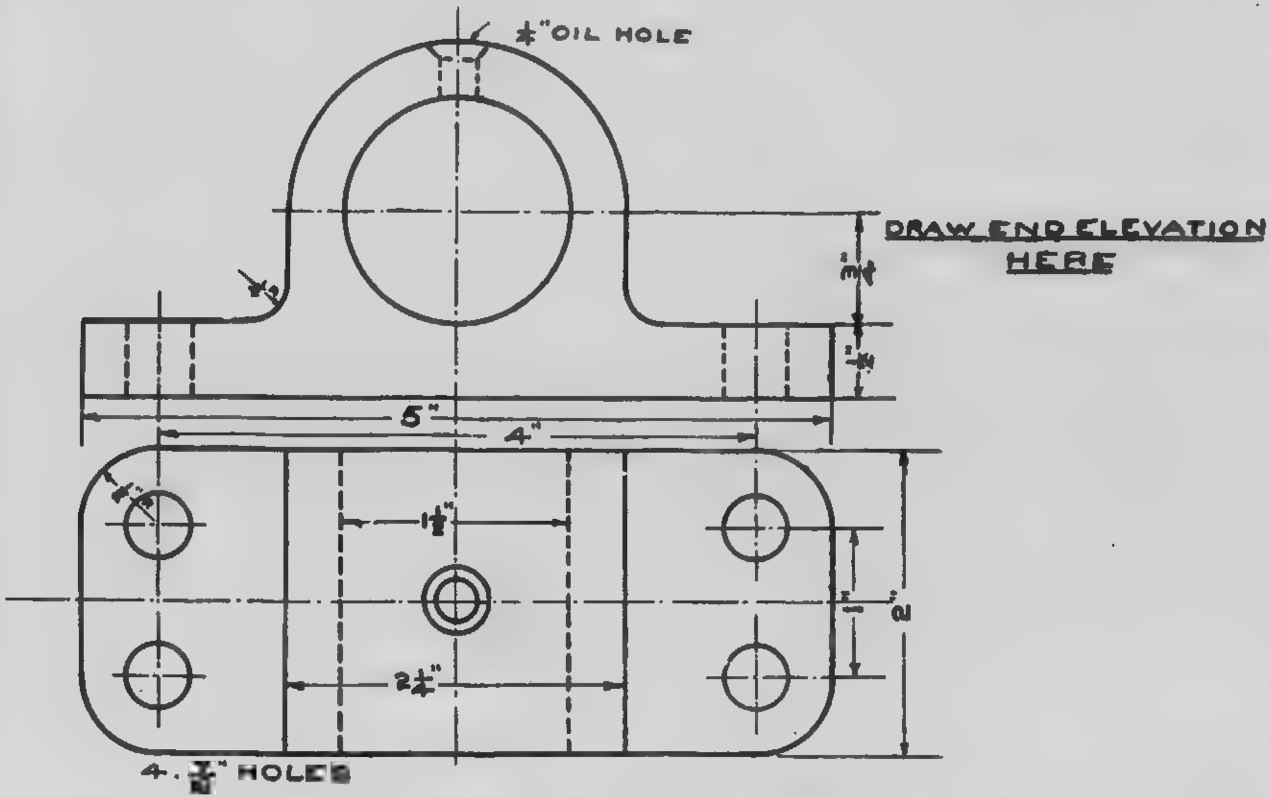


KING PIN GUIDE CASTING

DRAW HALF SIZE

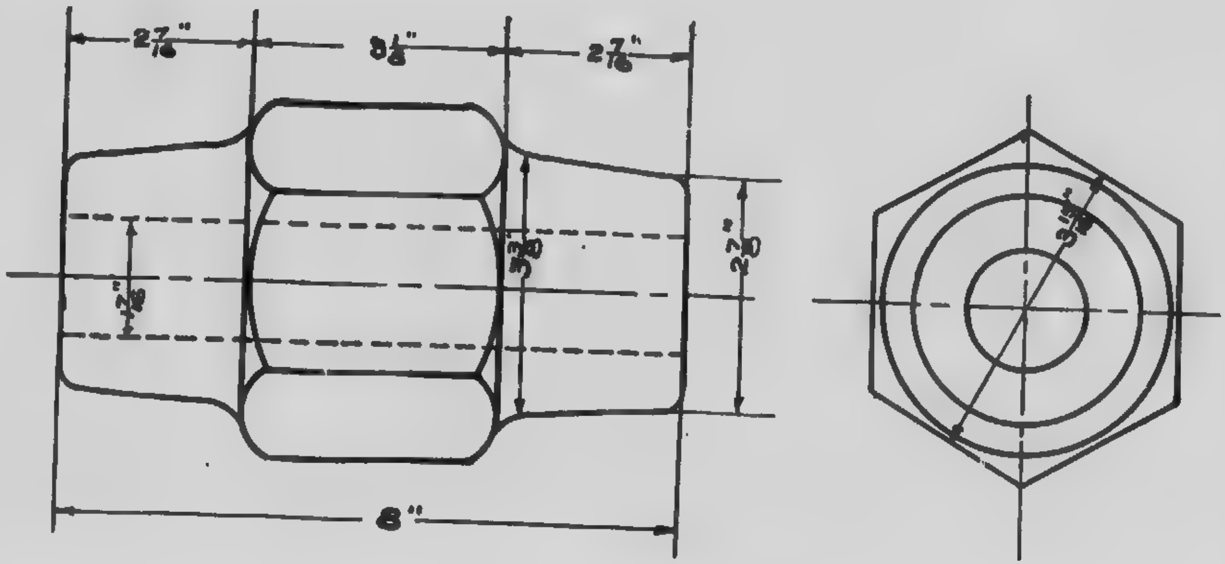


—BACK CYLINDER COVER—
FOR
—AIR ENGINE—
DRAW FULL SIZE



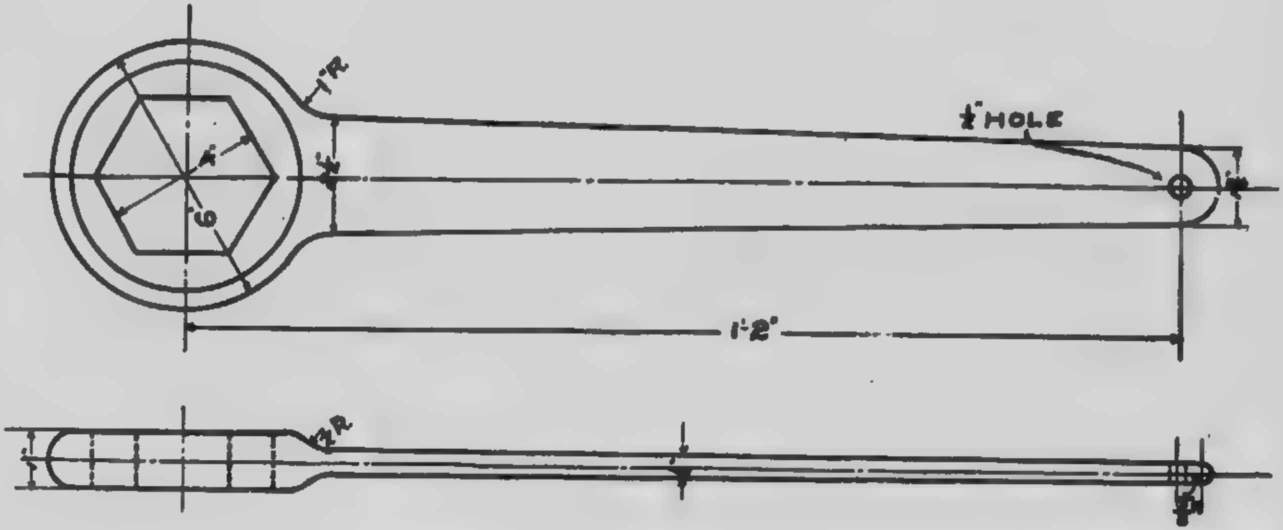
—CAST IRON BRACKET—

DRAW FULL SIZE



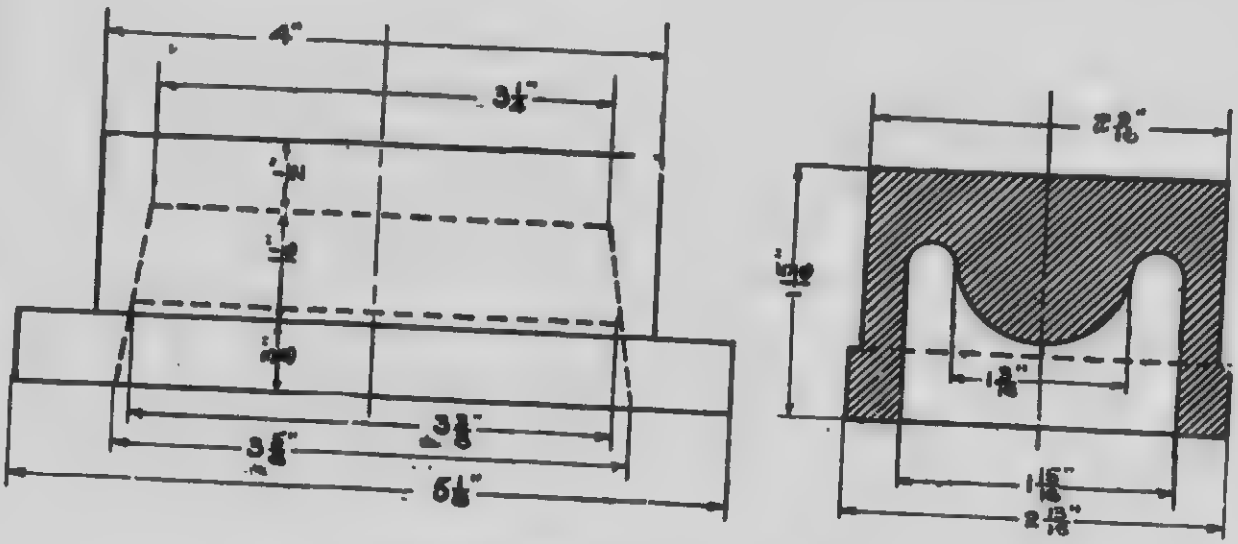
—TURN BUCKLE—

—DRAW FULL SIZE—



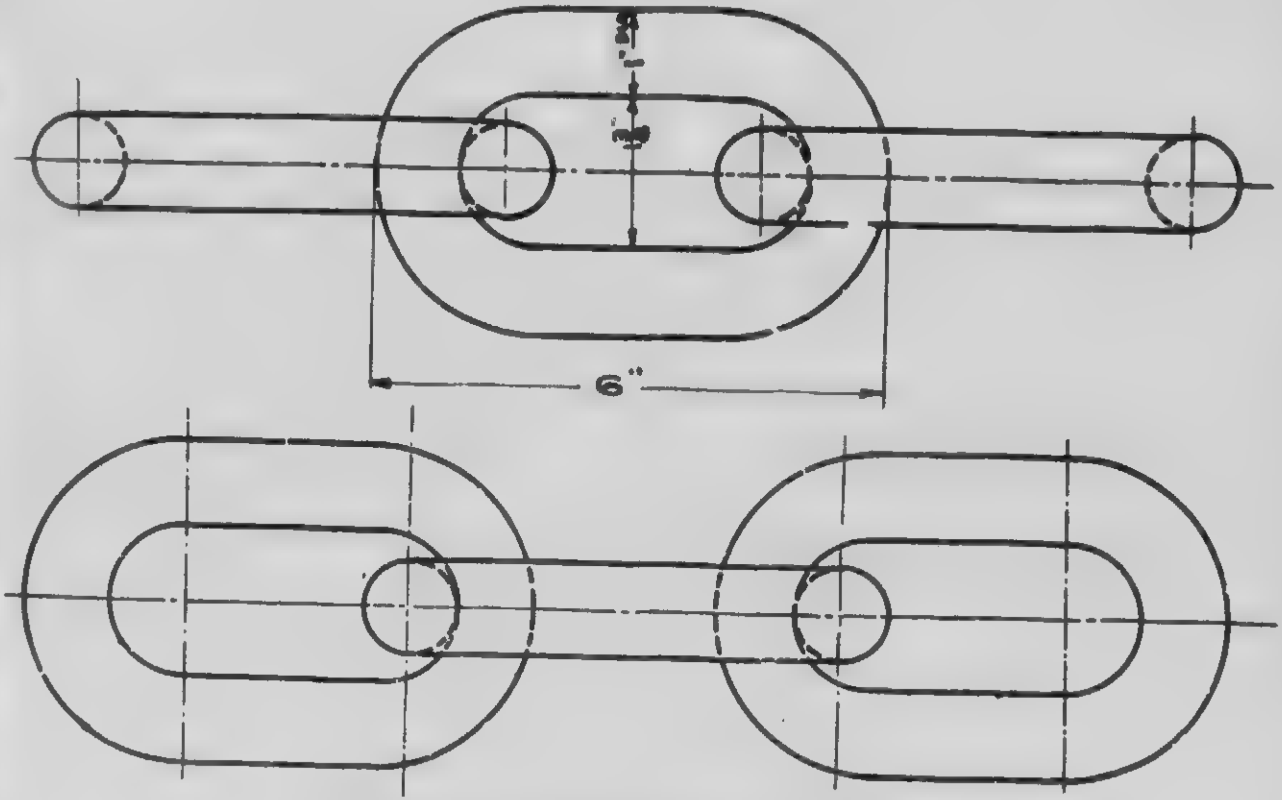
—CRANK PIN WRENCH—

—DRAW HALF SIZE—



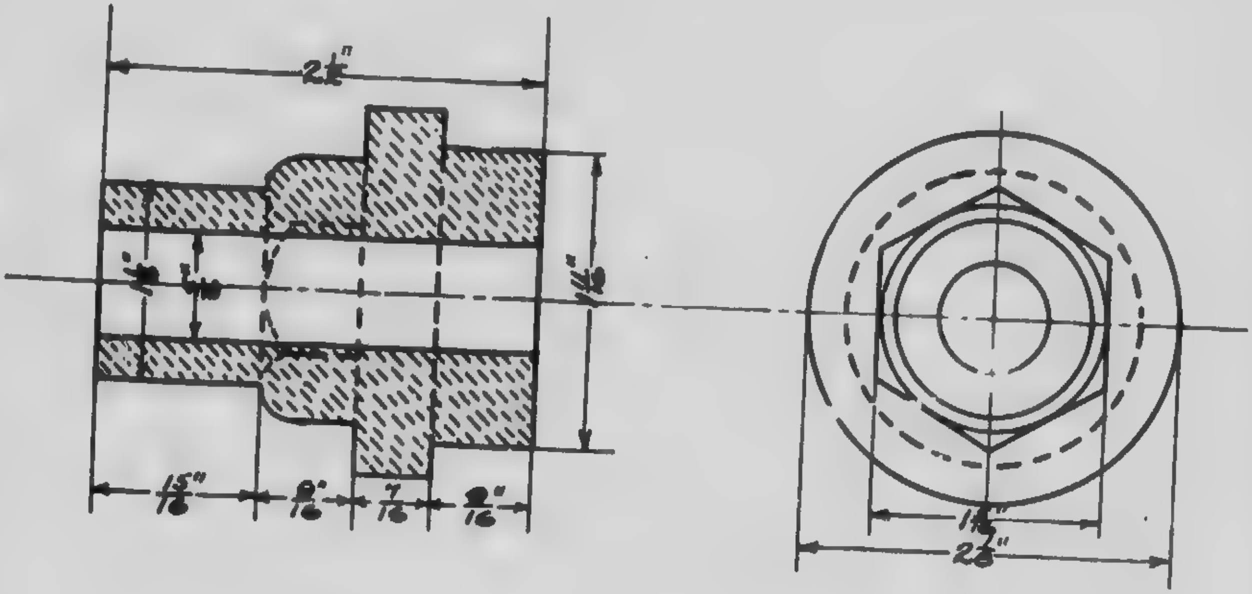
MAIN VALVE FOR AIR ENGINE

DRAW FULL SIZE



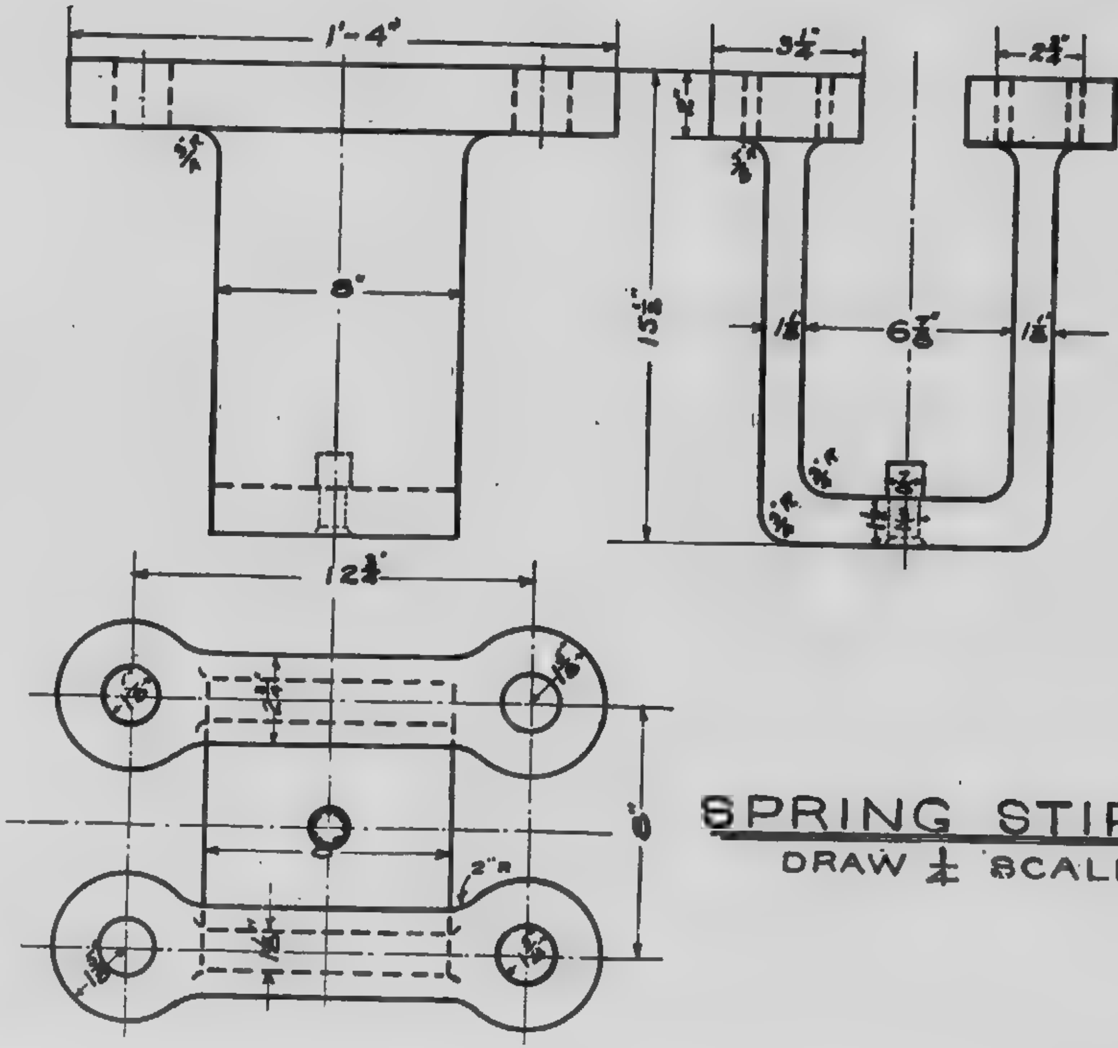
STANDARD 1 INCH CHAIN

DRAW HALF SIZE

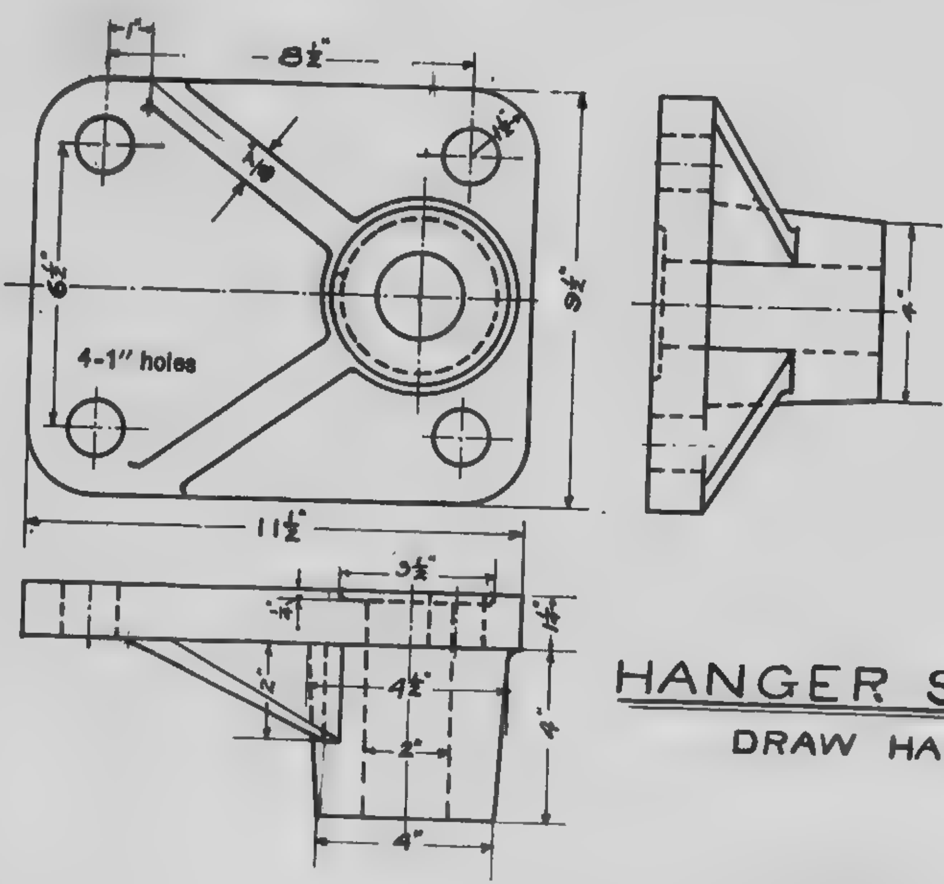


BRASS CONNECTION

DRAW FULL SIZE

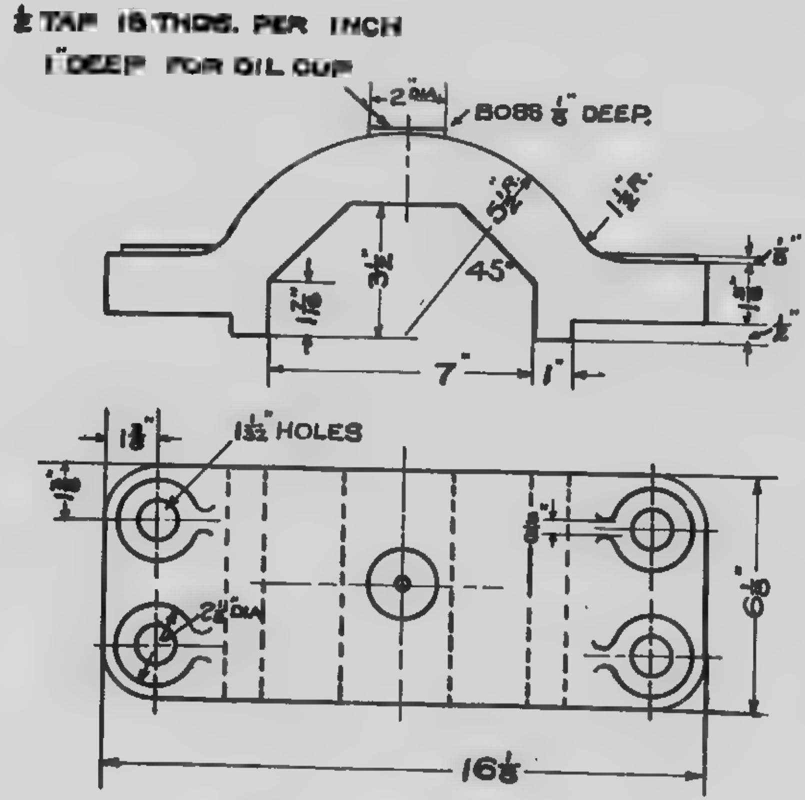


SPRING STIRRUP
DRAW ¼ SCALE



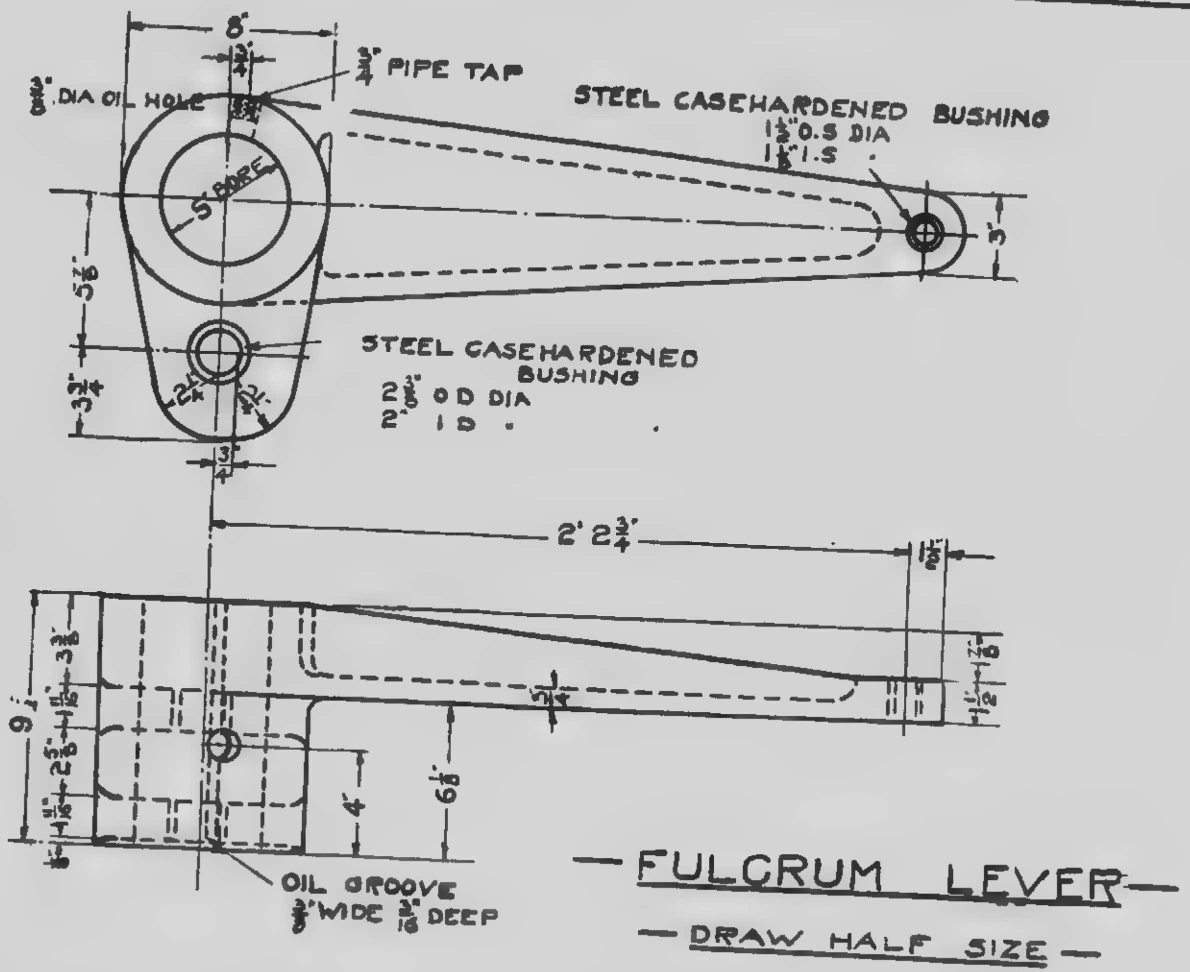
HANGER SUPPORT

DRAW HALF SIZE

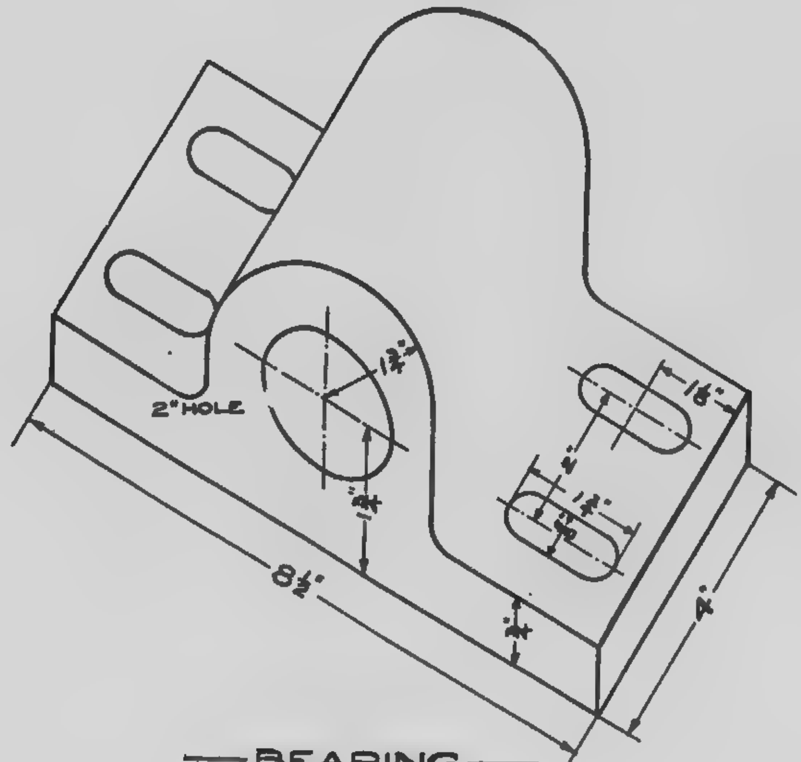


CAP FOR PLUMMER BLOCK

DRAW HALF SIZE

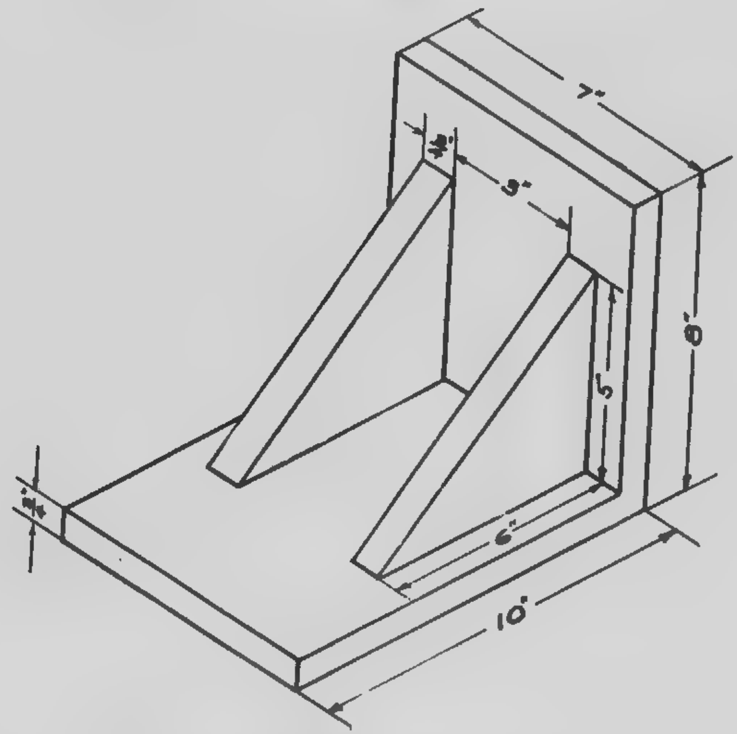

3/4" PIPE TAP
DIA OIL HOLE
5" BORE
STEEL CASEHARDENED BUSHING
1 1/2" O.S DIA
1 1/8" I.S
STEEL CASEHARDENED
BUSHING
2 3/8 O D DIA
2" I D
2' 2 3/4"
OIL GROOVE
3/8" WIDE 3/16" DEEP
FULCRUM LEVER
DRAW HALF SIZE

DRAW PLAN AND ELEVATION
DRAW HALF SIZE



— BEARING —

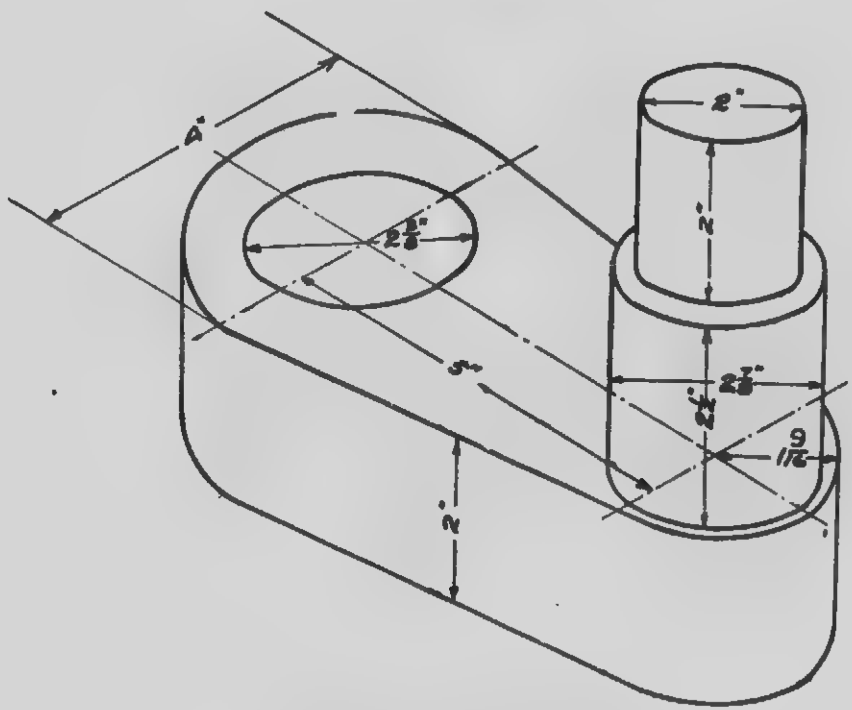
DRAW PLAN, SIDE AND END ELEVATION



—ANGLE PLATE—

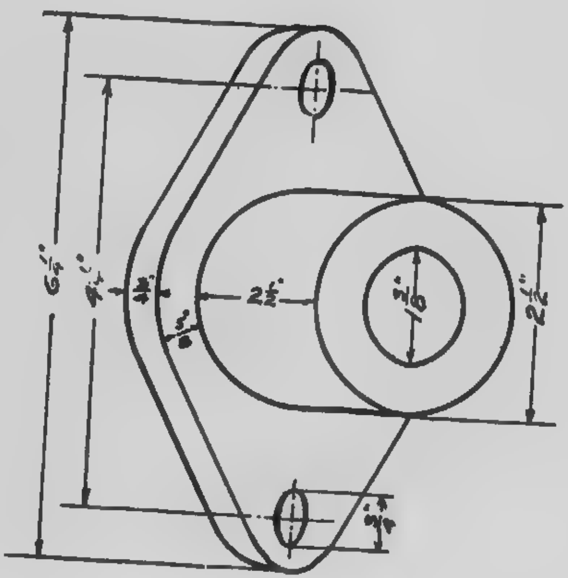
DRAW HALF SIZE

DRAW PLAN AND ELEVATION
SCALE HALF SIZE



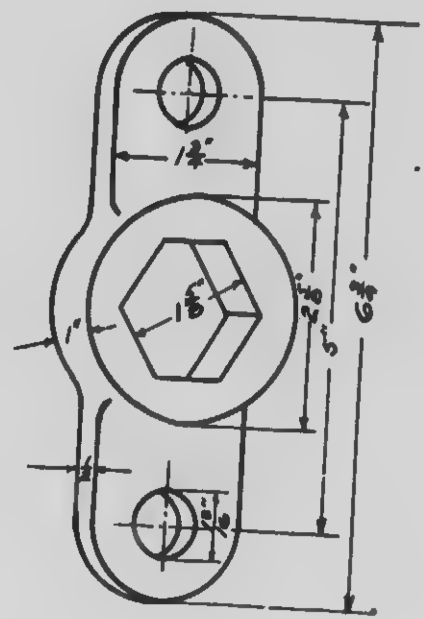
—CRANK PIN—

DRAW PLAN AND ELEVATION OF EACH



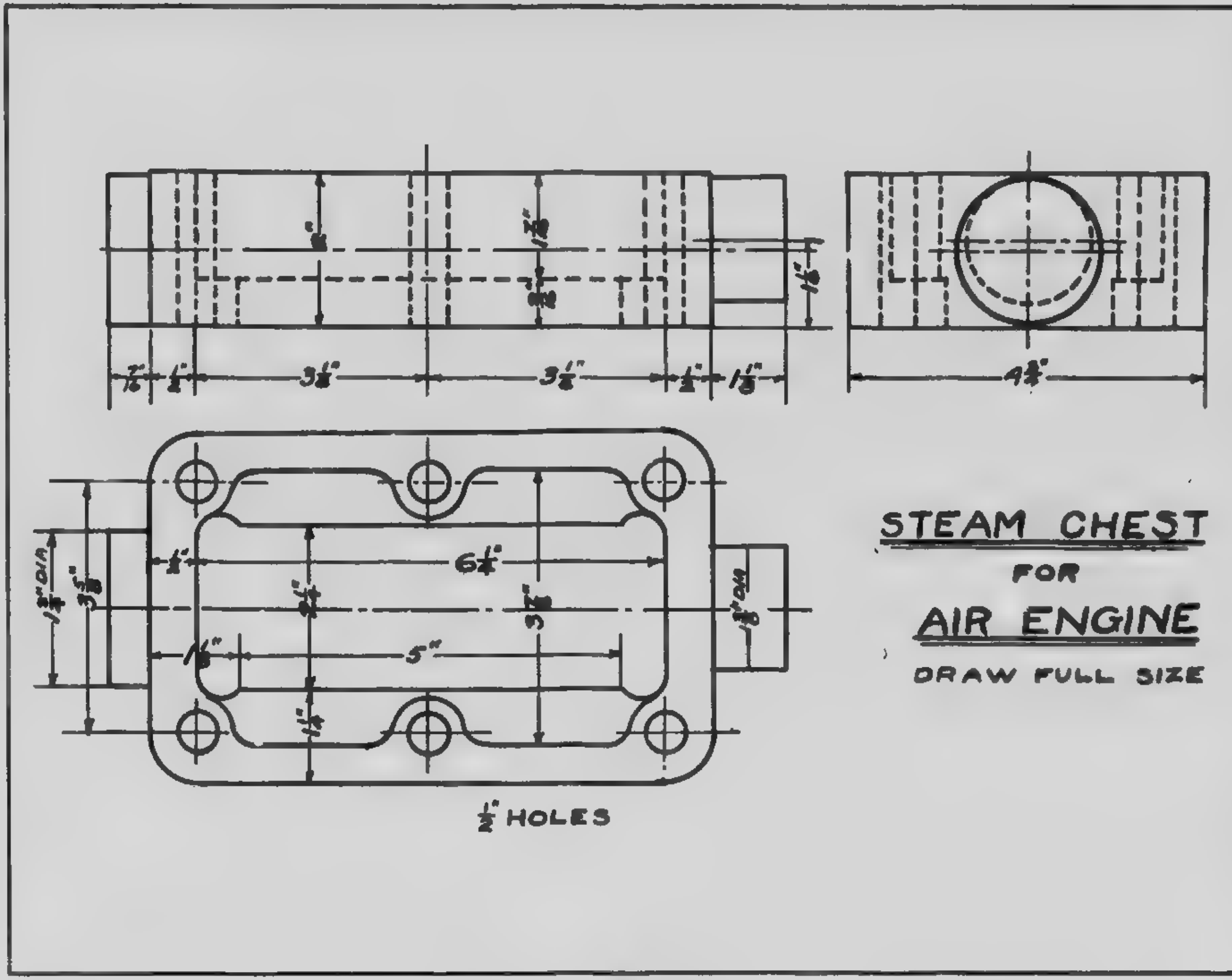
-GLAND-

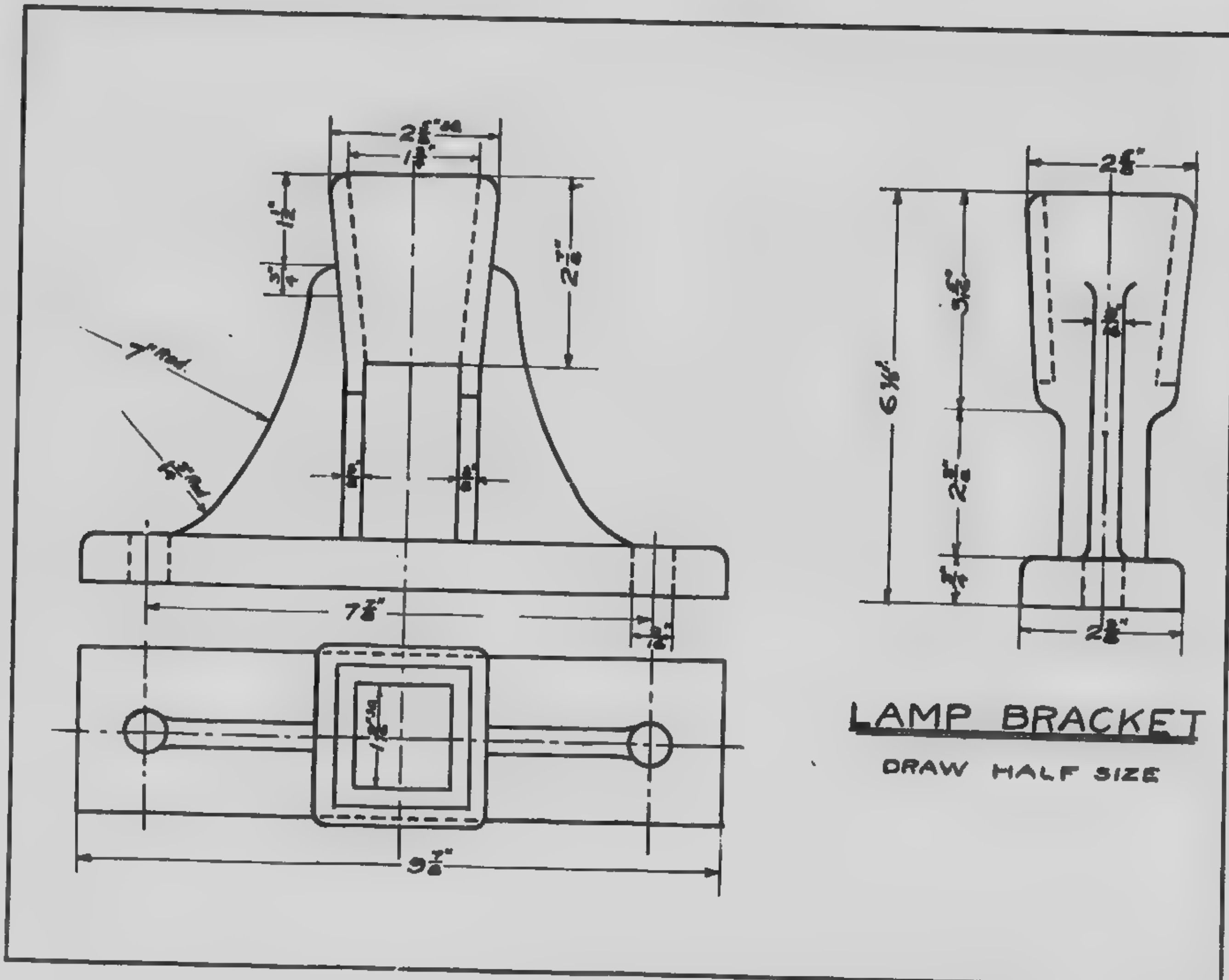
DRAW FULL SIZE

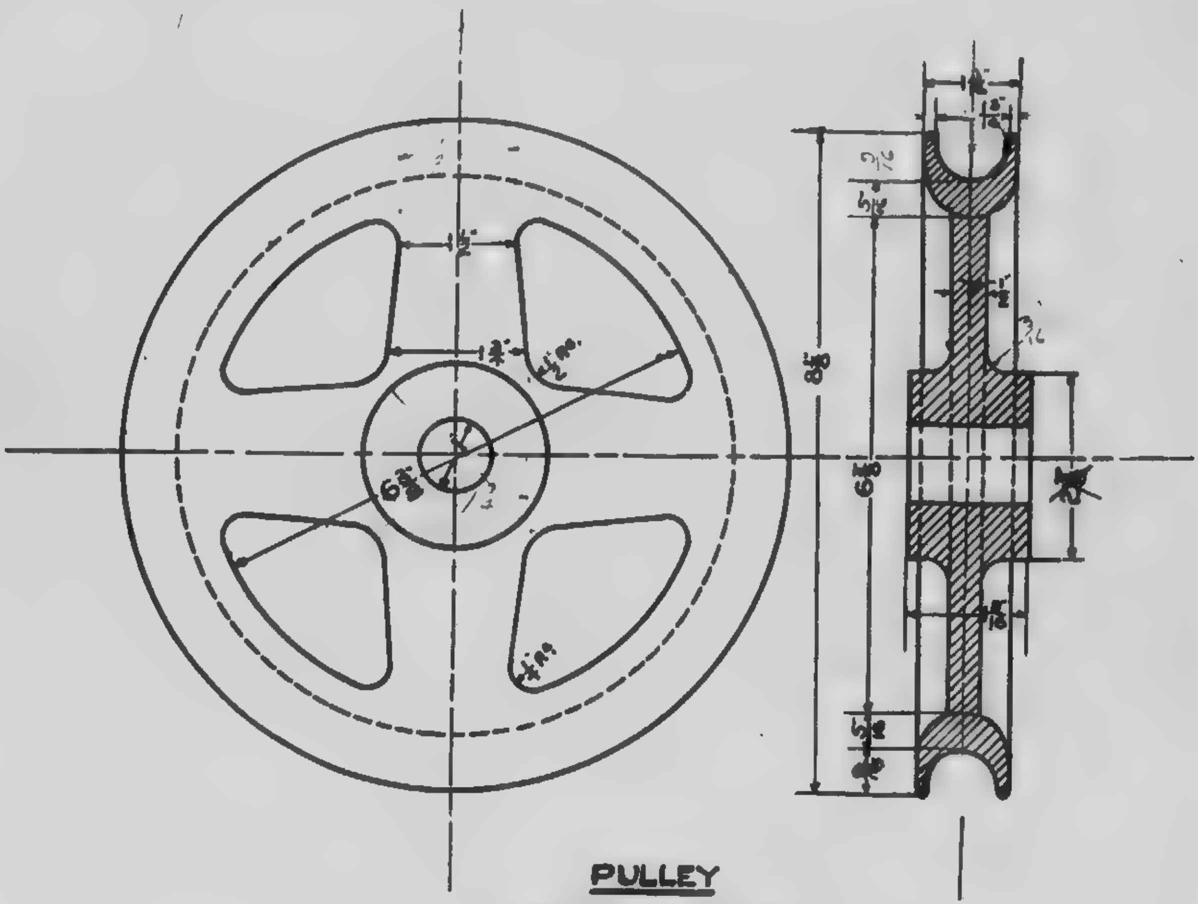


-DRIVING DOG-

DRAW FULL SIZE

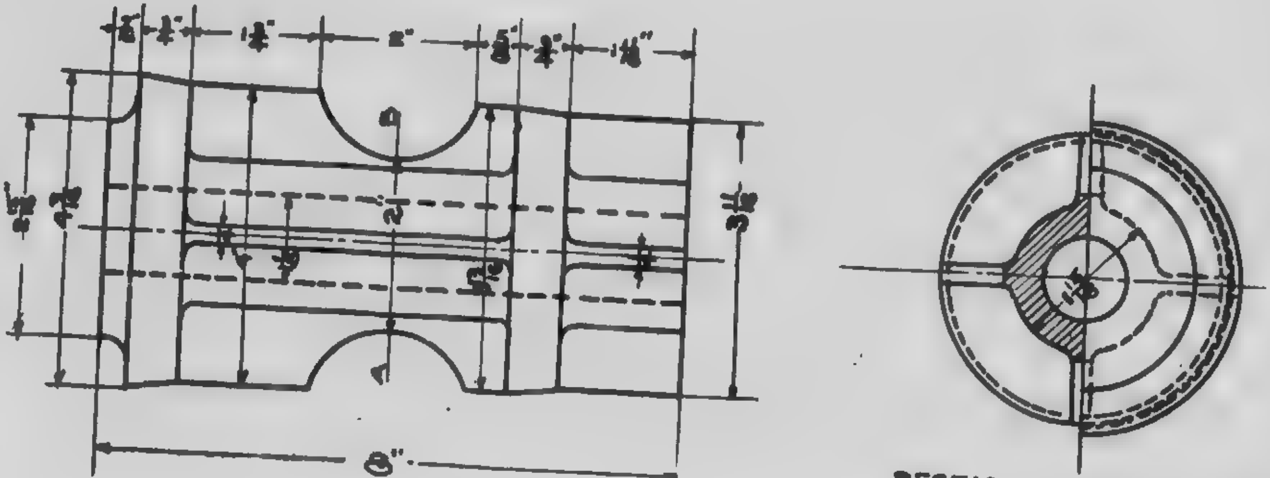

STEAM CHEST
FOR
AIR ENGINE
DRAW FULL SIZE
½" HOLES
6¼"
5"


LAMP BRACKET
DRAW HALF SIZE



PULLEY

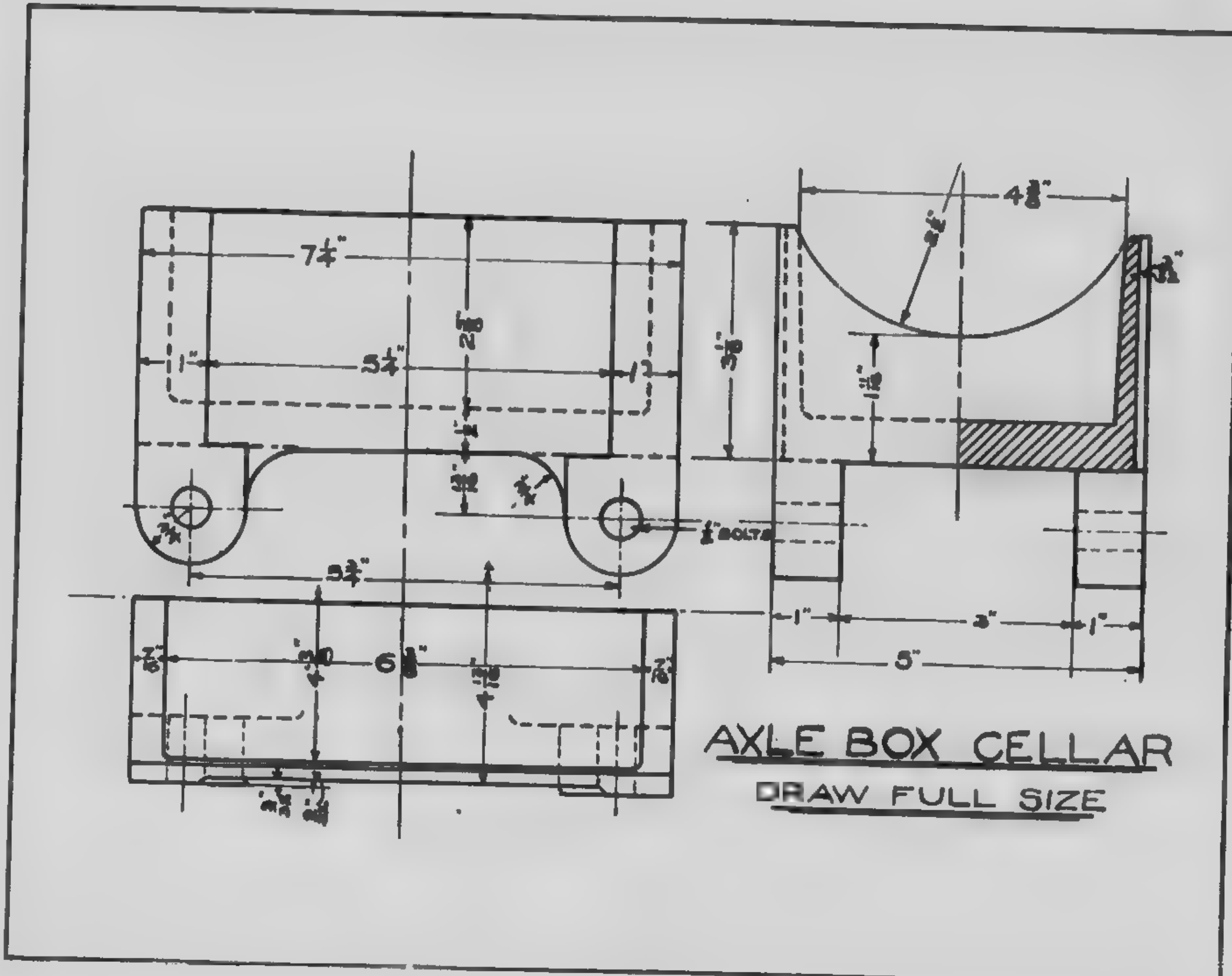
DRAW FULL SIZE

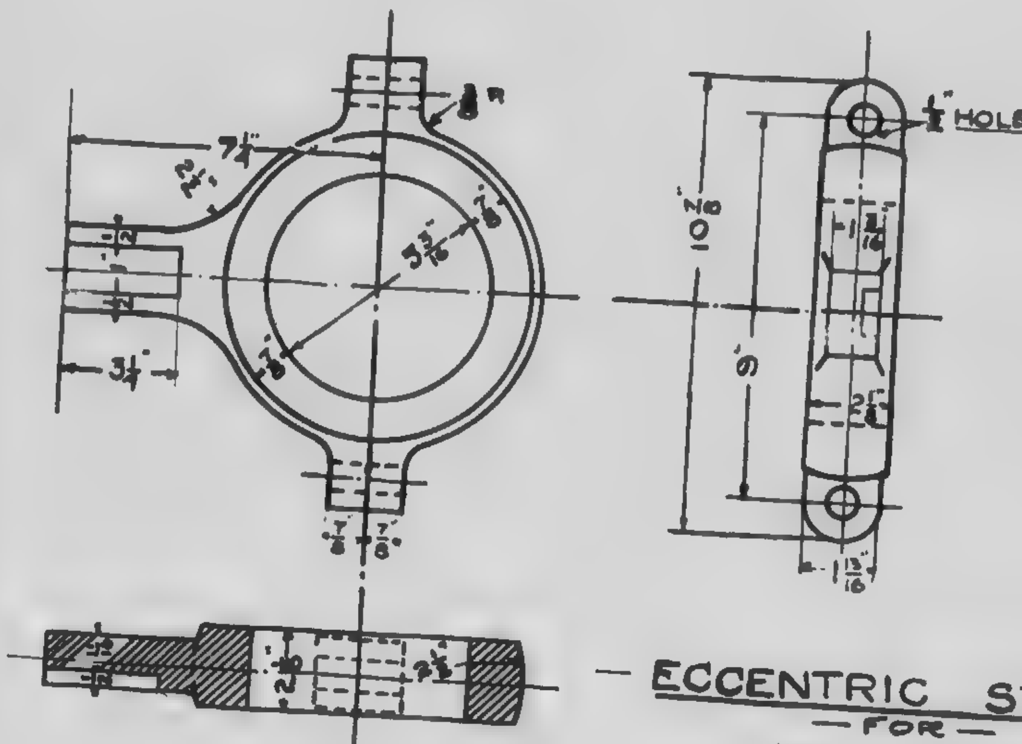


SECTION THROUGH A.B

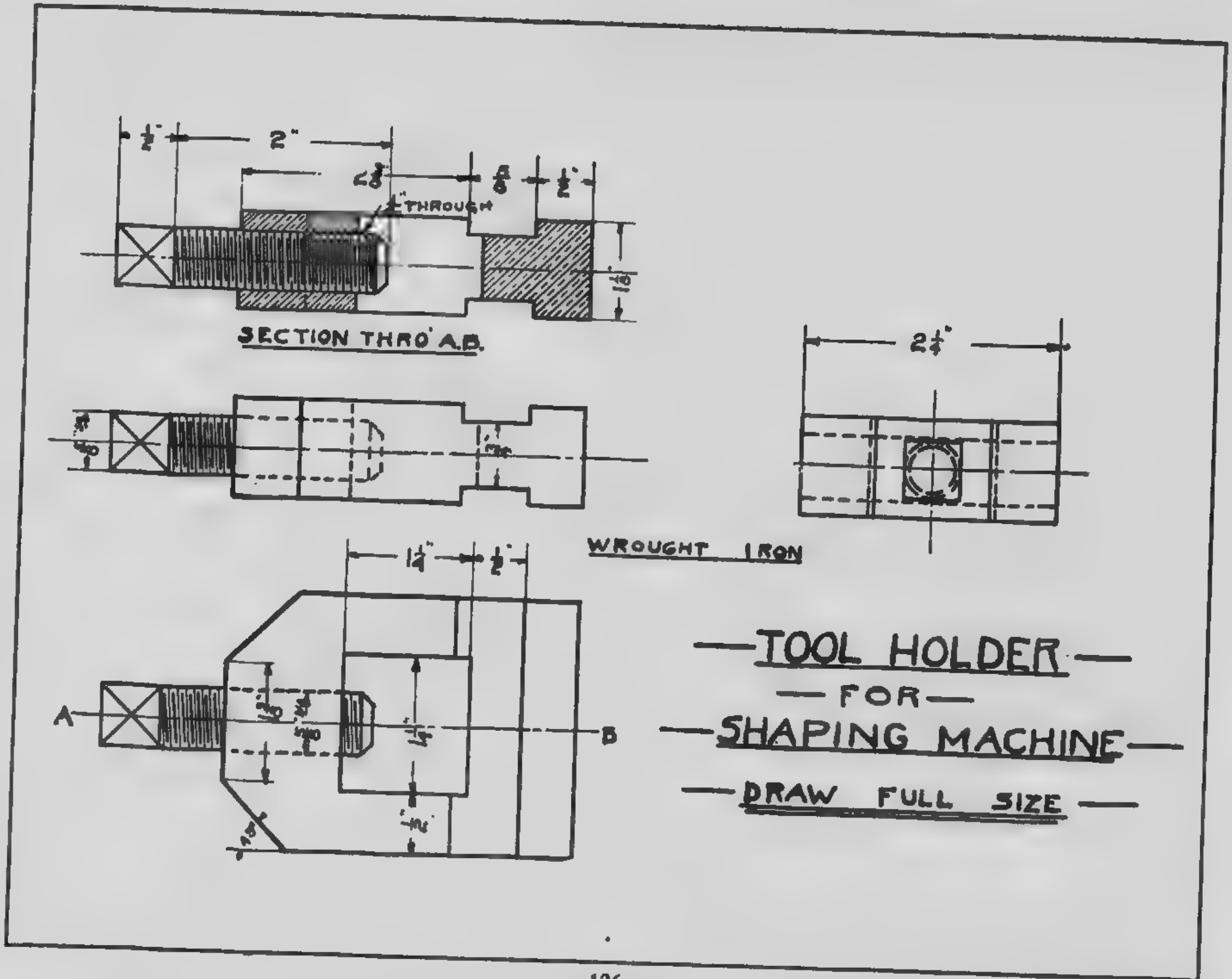
THROTTLE VALVE

DRAW FULL SIZE


AXLE BOX CELLAR
DRAW FULL SIZE

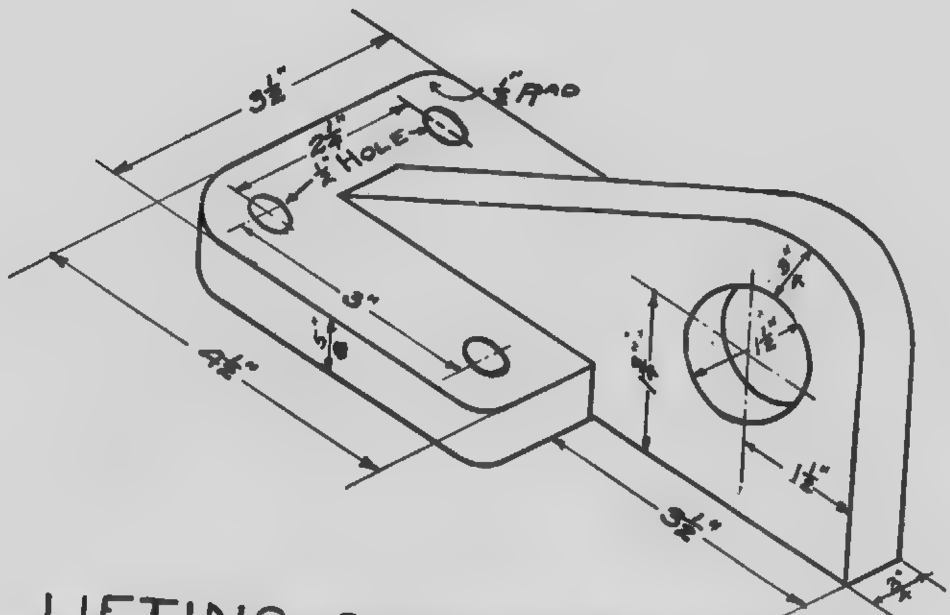


ECCENTRIC STRAP
FOR
AIR ENGINE
DRAW HALF SIZE



SECTION THRO' A.B.
WROUGHT IRON
A
B
TOOL HOLDER
FOR
SHAPING MACHINE
DRAW FULL SIZE

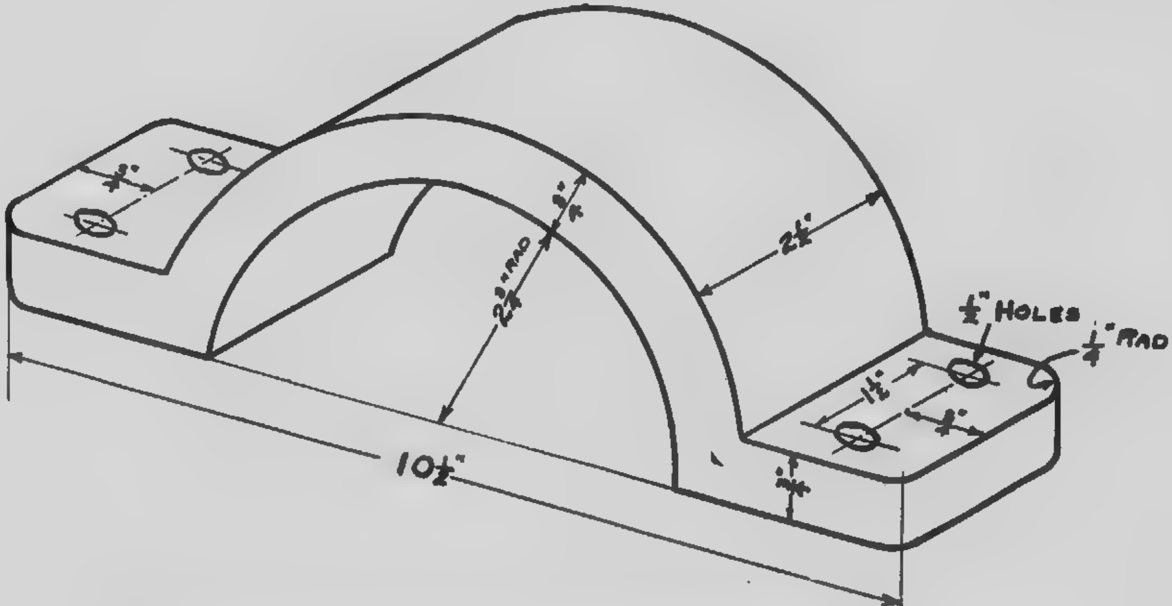
DRAW PLAN, ELEVATION AND END VIEW



LIFTING SHAFT BRACKET

DRAW FULL SIZE

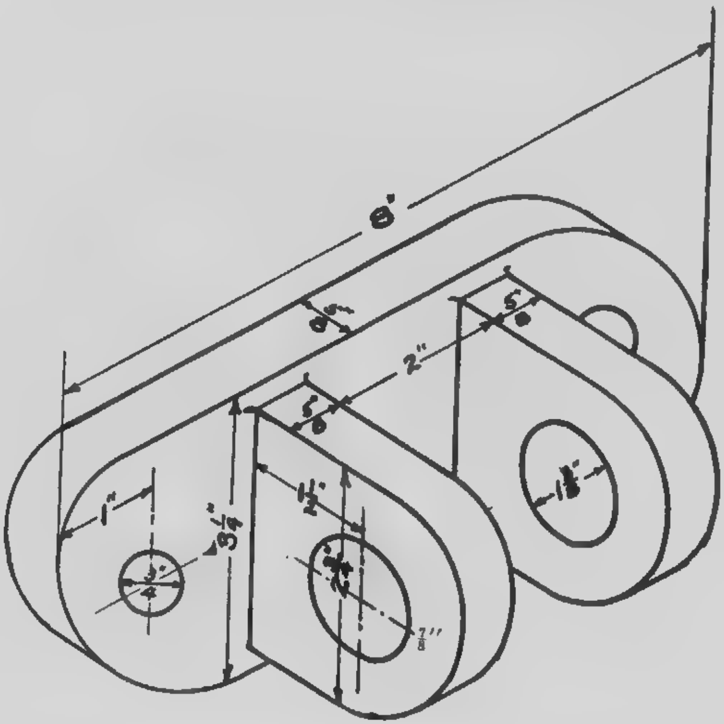
DRAW PLAN AND ELEVATION



STRAP FOR COLUMN

DRAW FULL SIZE

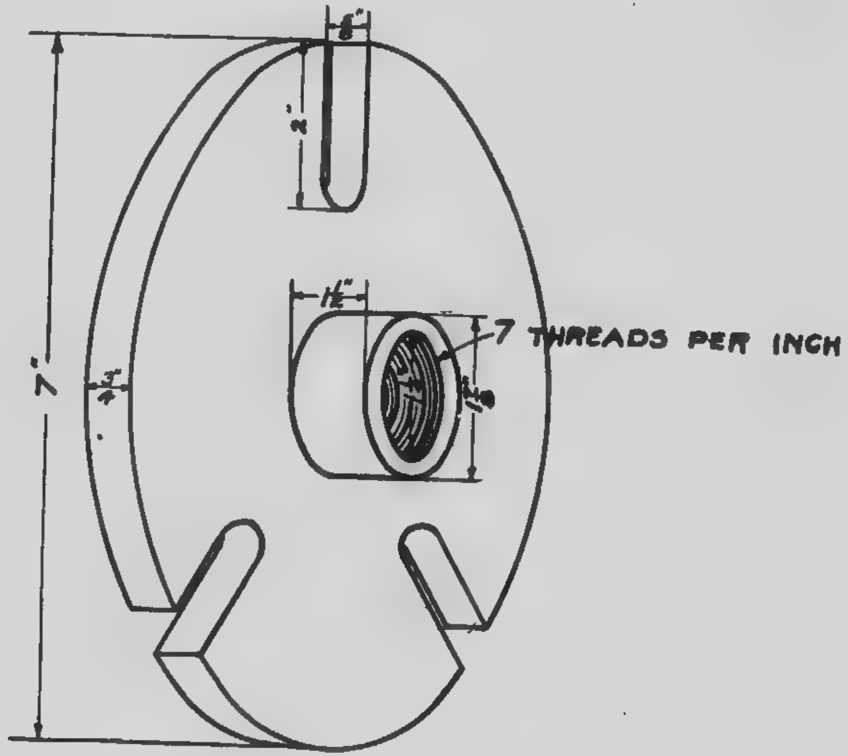
DRAW PLAN, ELEVATION AND END VIEW



TIE ROD BRACKET

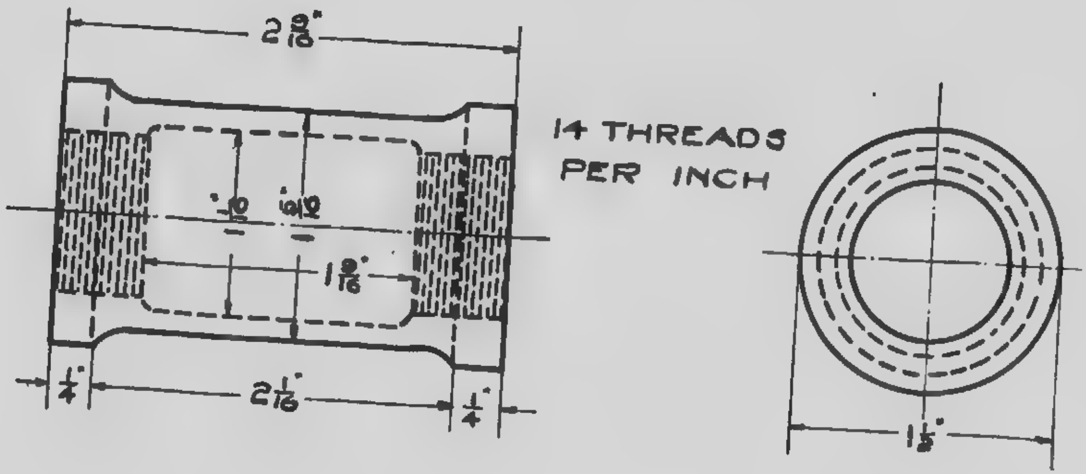
FULL SIZE

DRAW PLAN AND ELEVATION



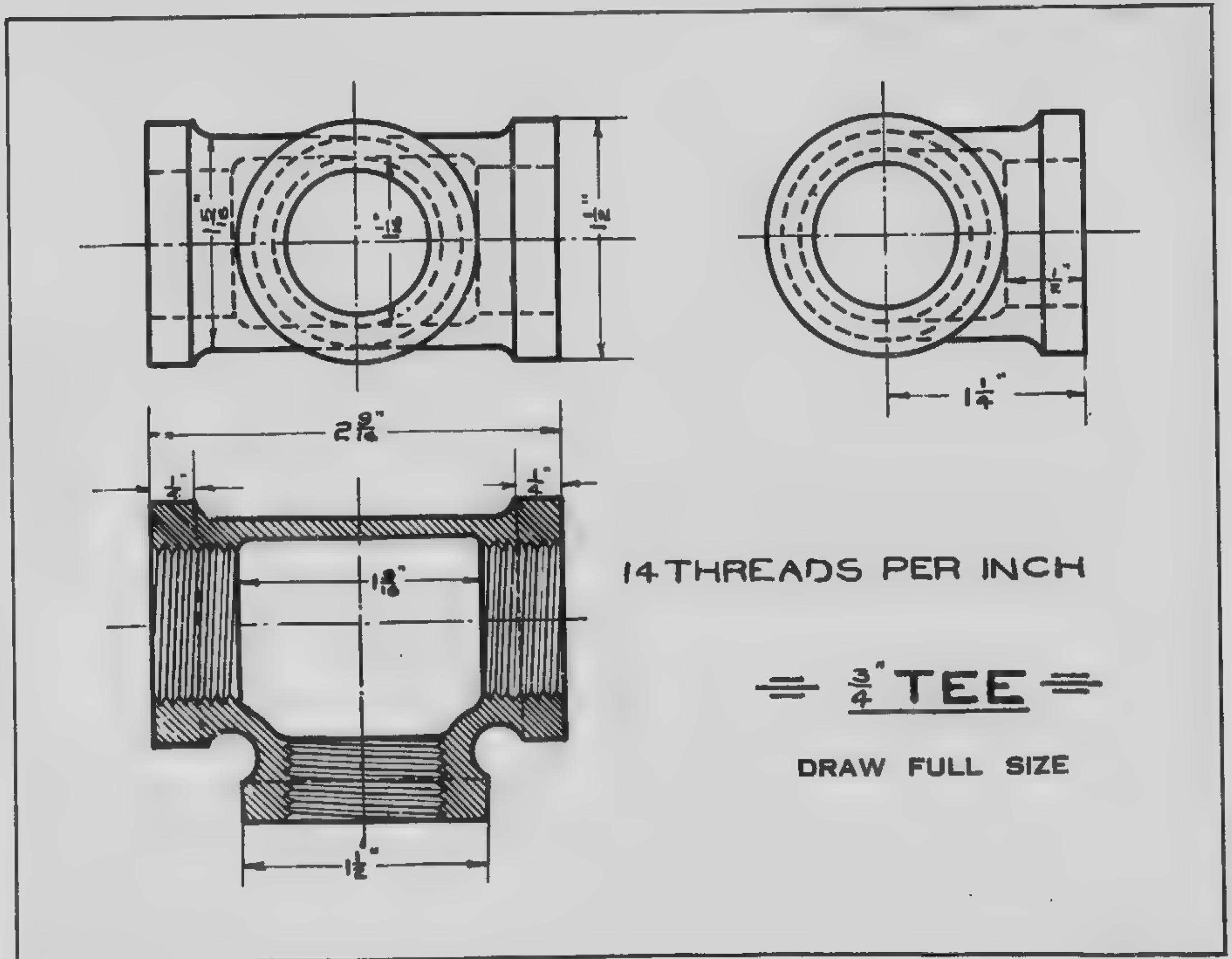
—FACE PLATE—

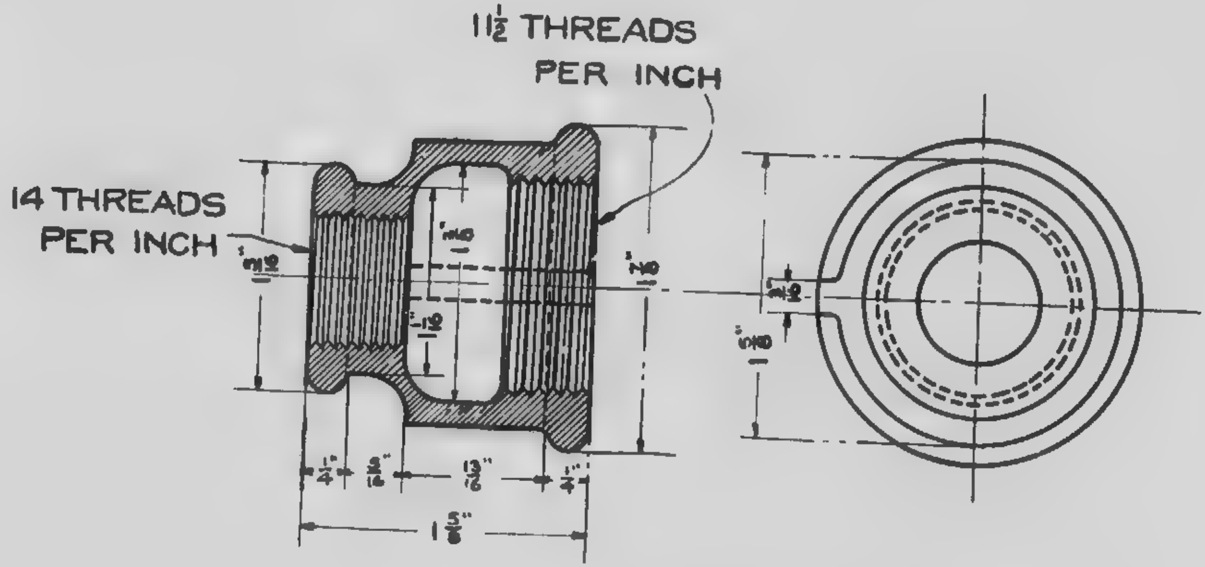
DRAW FULL SIZE



— $\frac{3}{4}$" COUPLING —

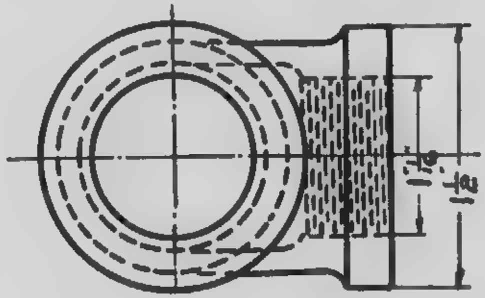
DRAW FULL SIZE


14 THREADS PER INCH
3/4" TEE
DRAW FULL SIZE
2 9/16"
1/4"
1/4"
1 3/16"
1 1/2"
1 1/4"
1/2"

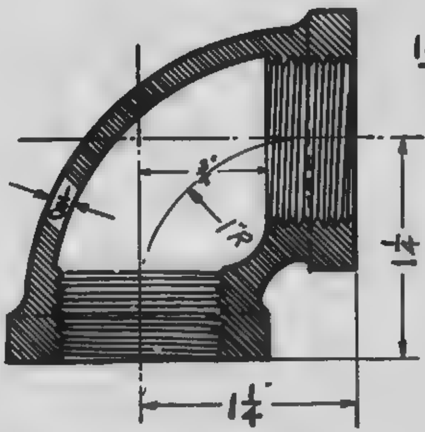


1" TO ½ REDUCER

DRAW FULL SIZE



DRAW END VIEW HERE

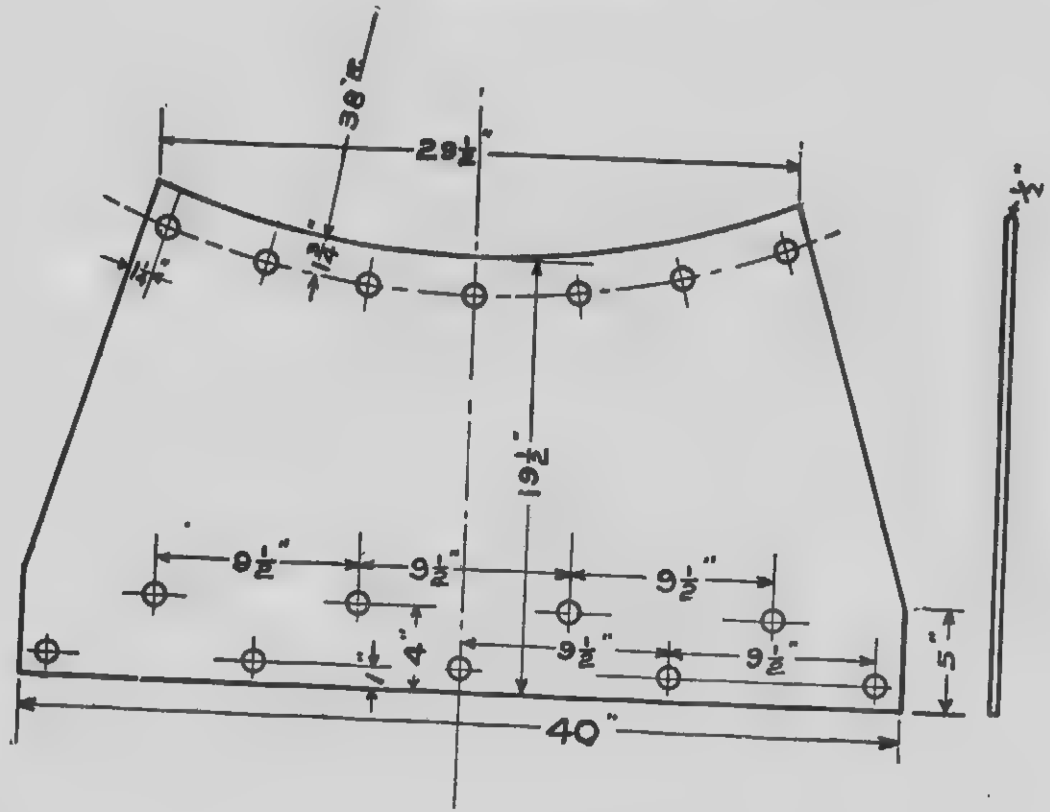


14 THREADS PER INCH

— 90° ELBOW —

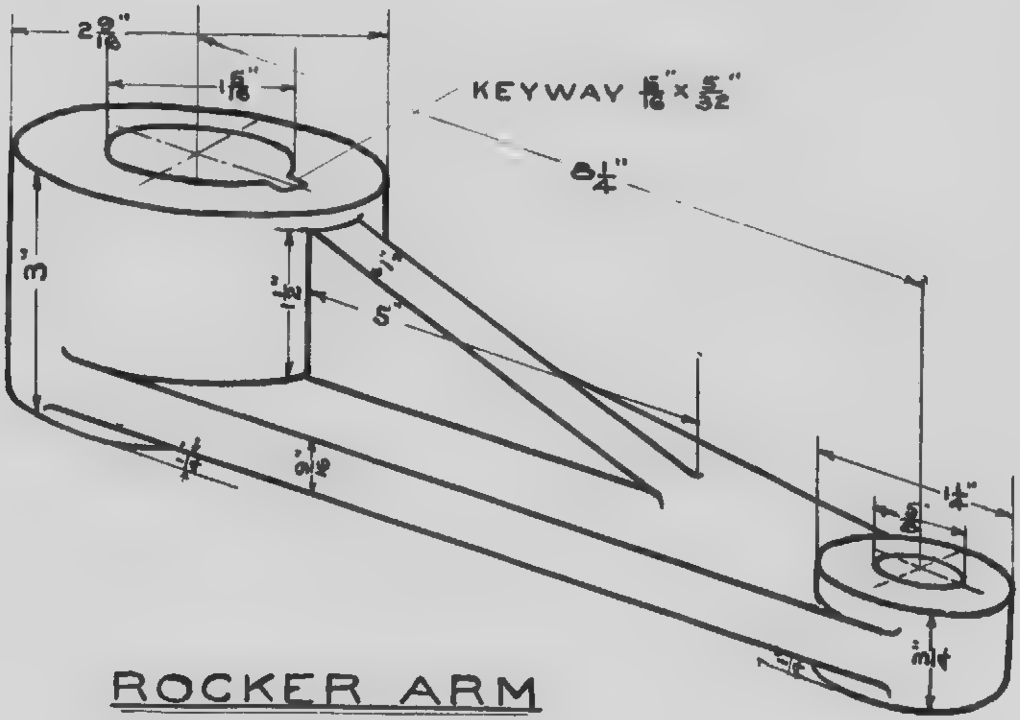
DRAW FULL SIZE

WAIST SHEET



DRAW TO A SCALE 3 IN. 1 FT.

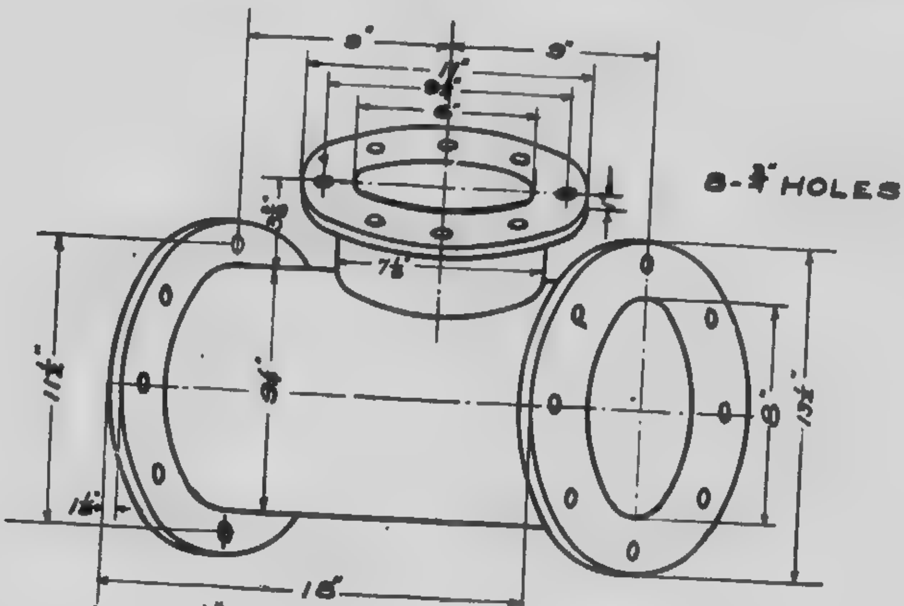
DRAW PLAN AND ELEVATION



ROCKER ARM

DRAW FULL SIZE

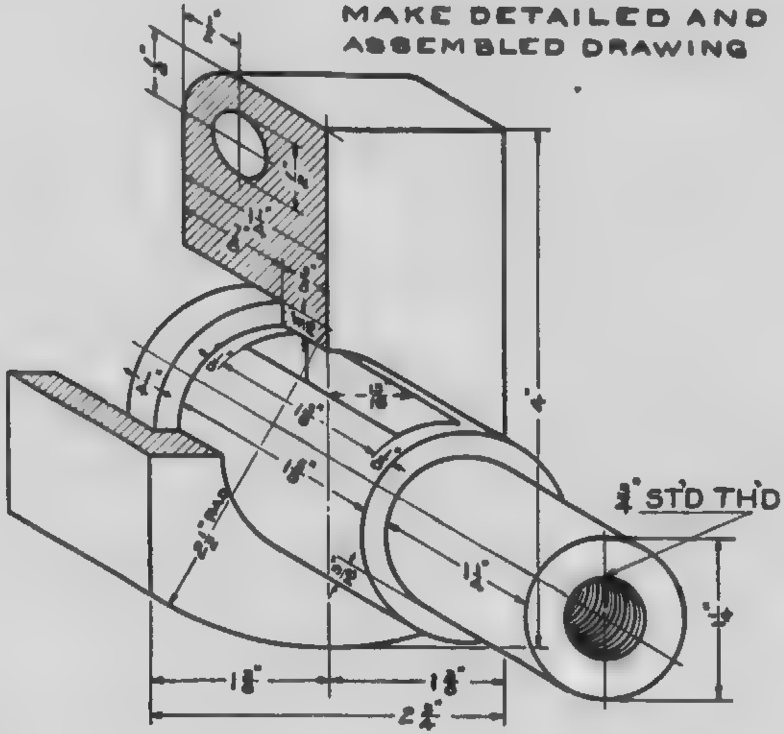
DRAW PLAN, ELEVATION AND END VIEW



½" FILLETS IN ALL CORNERS

8"×8"×6" TEE

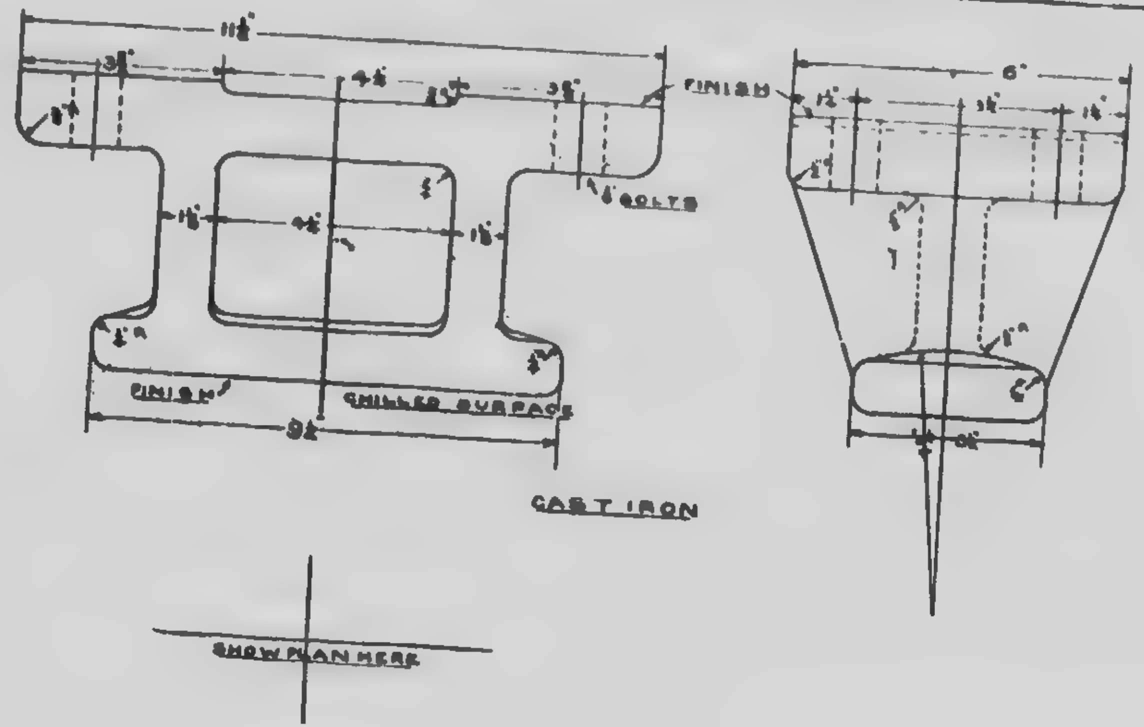
DRAW HALF SIZE



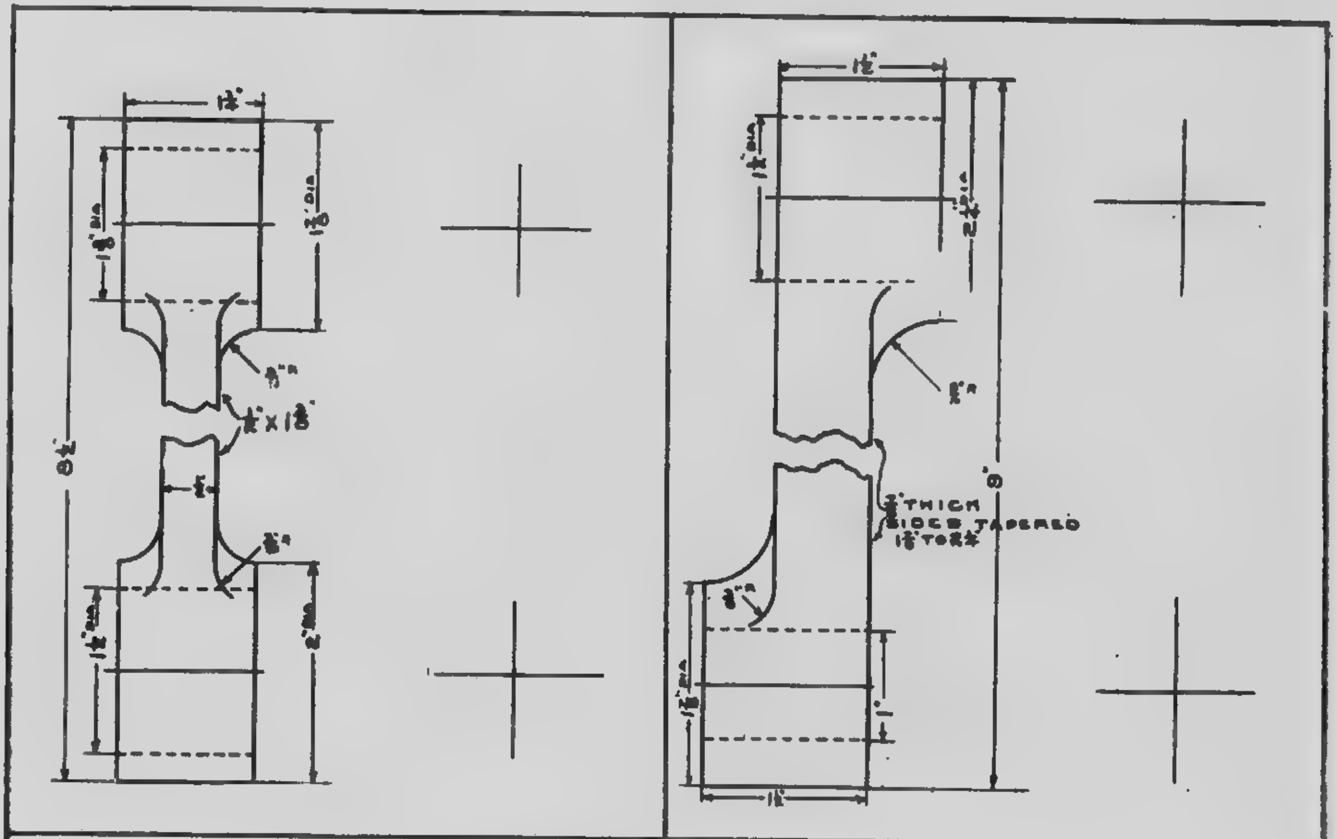
TOOL HOLDER AND SWING BLOCK

FOR SHAPER

DRAW FULL SIZE



TENDER FRAME SIDE BEARING
DRAW HALF SIZE

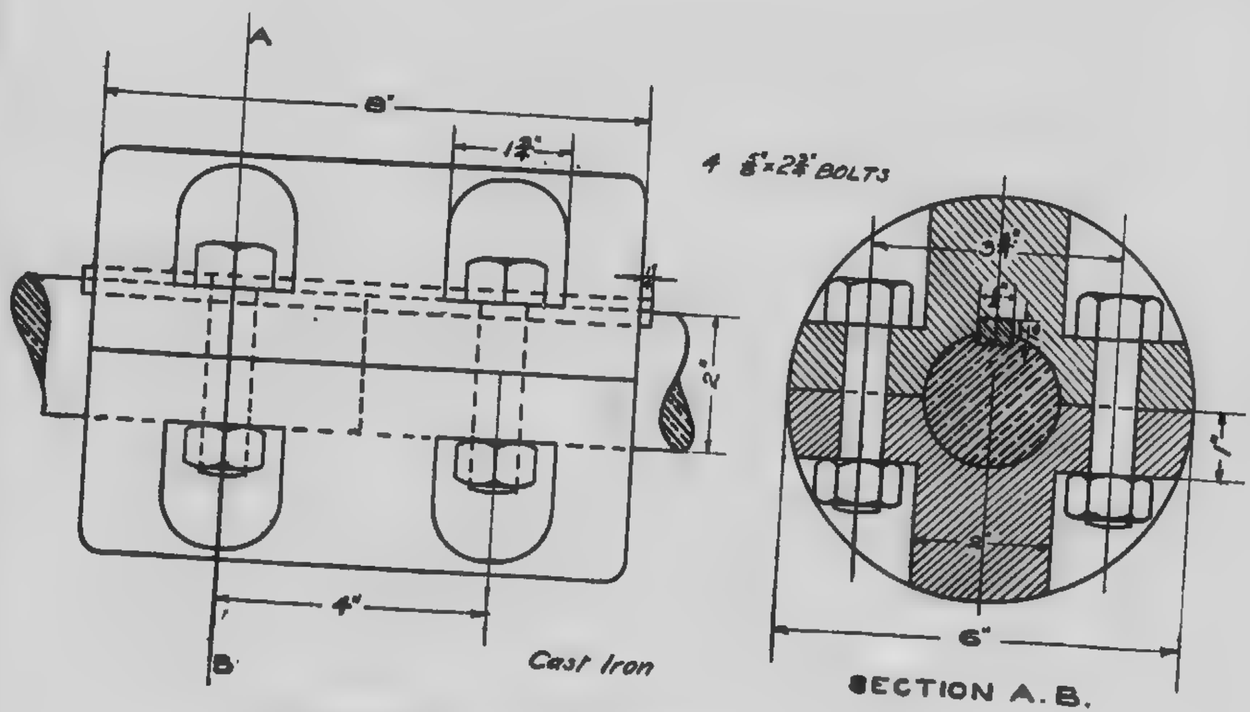


CONNECTING RODS

DRAW FULL SIZE

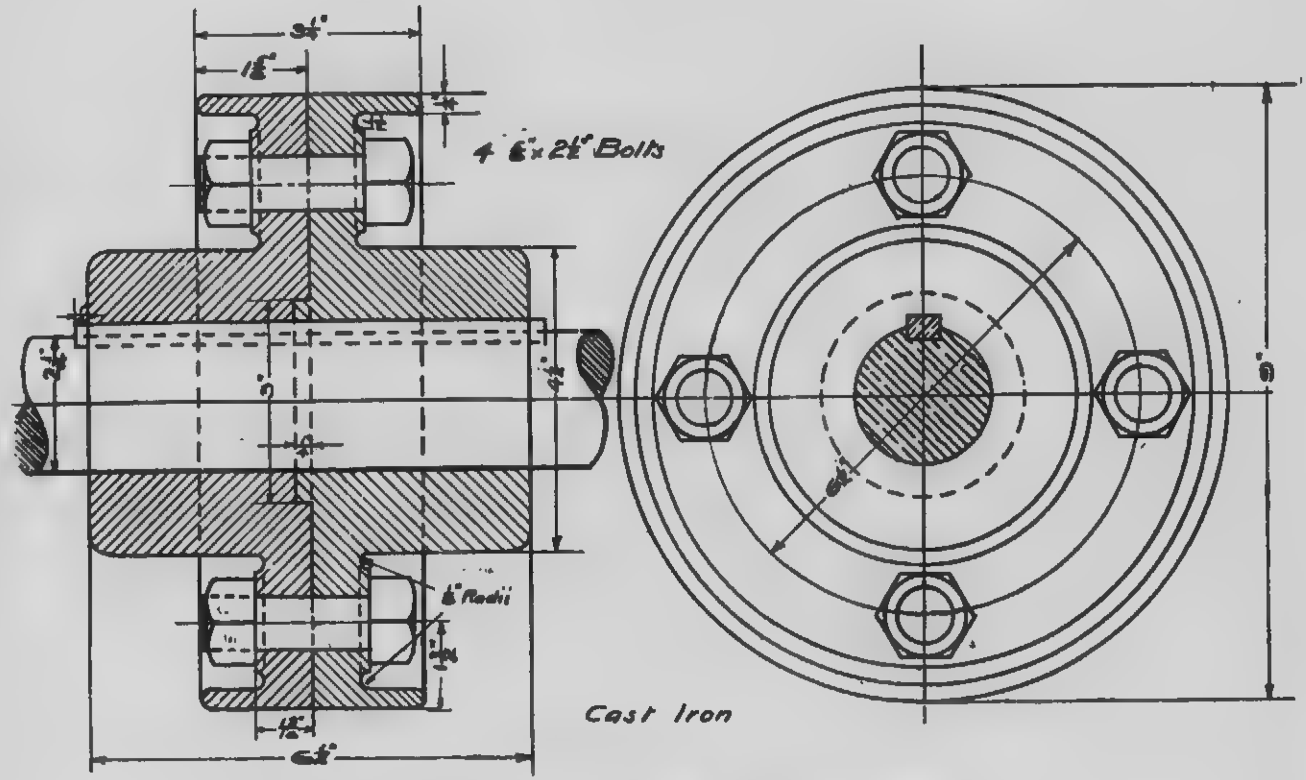
NOTE

SHOW PLAN & ELEVATION OF EACH MODEL. PUT IN ALL DIMENSIONS & TITLES



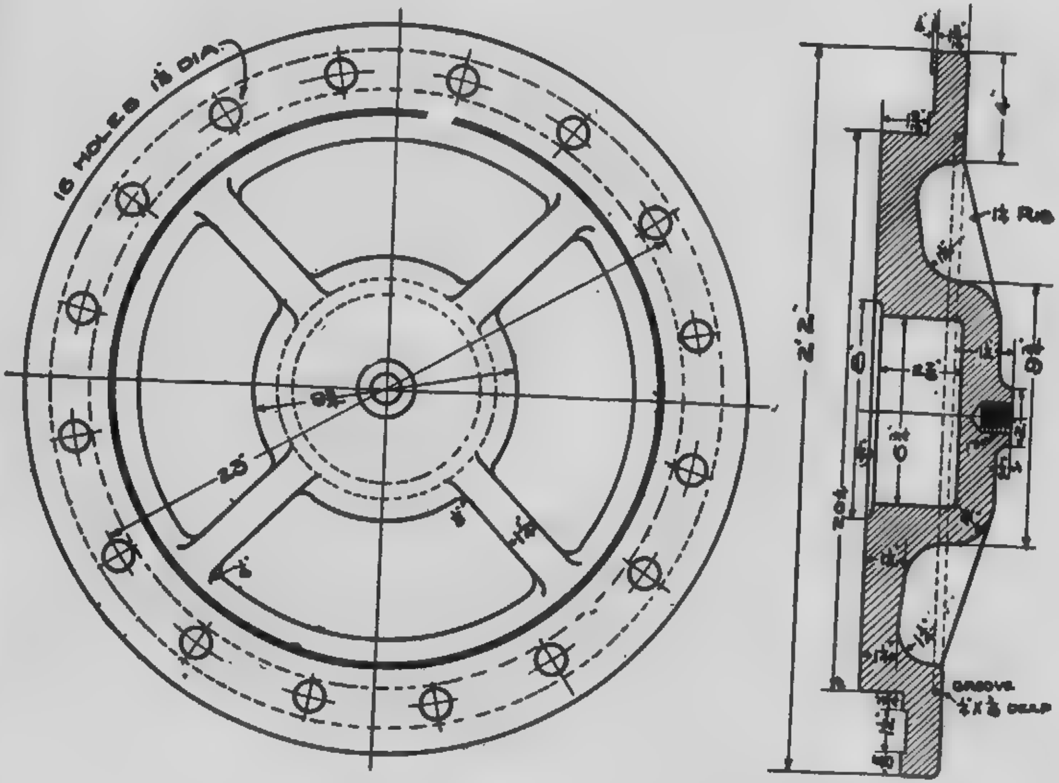
SHAFT COUPLING

DRAW FULL SIZE

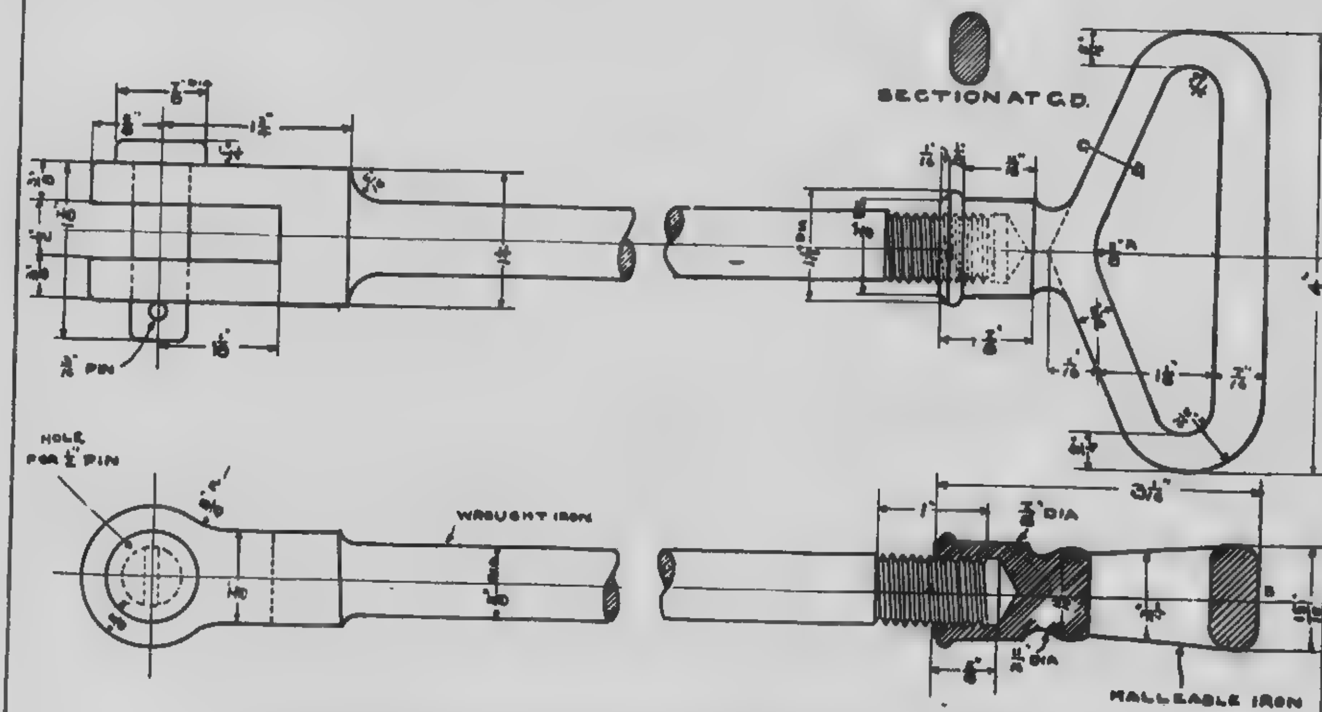


FLANGE COUPLING

DRAW FULL SIZE

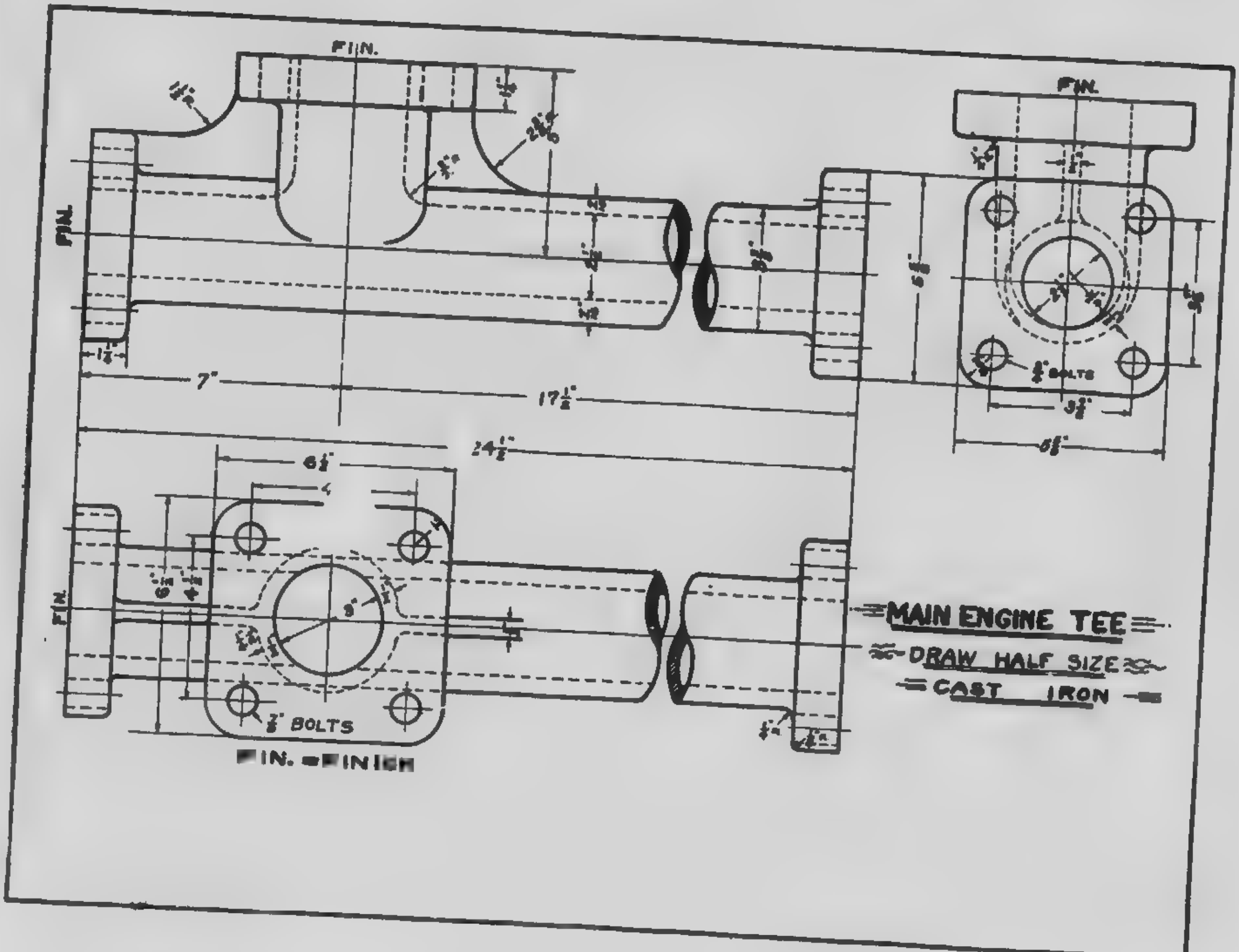


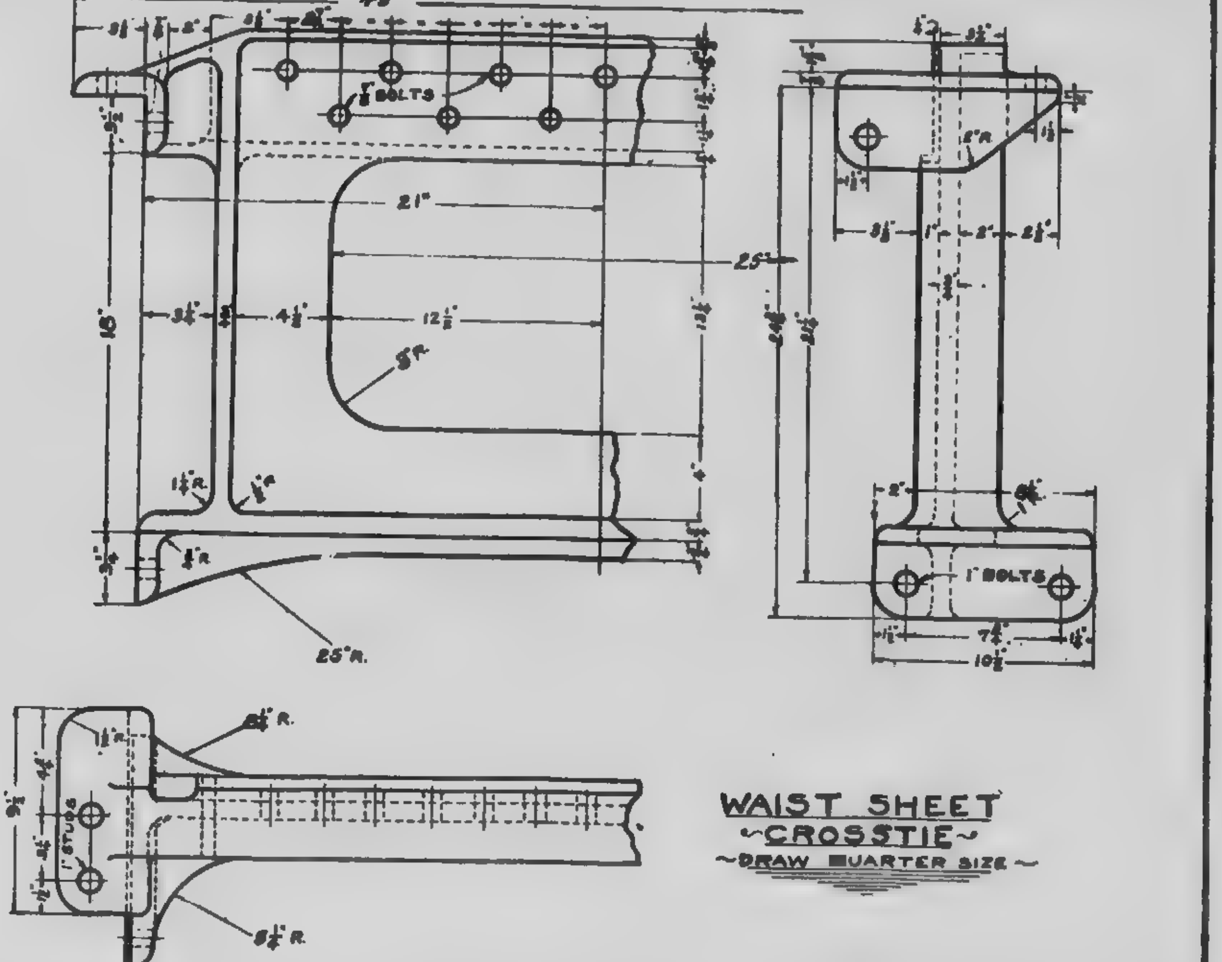
FRONT CYLINDER COVER
DRAW-HALF-SIZE



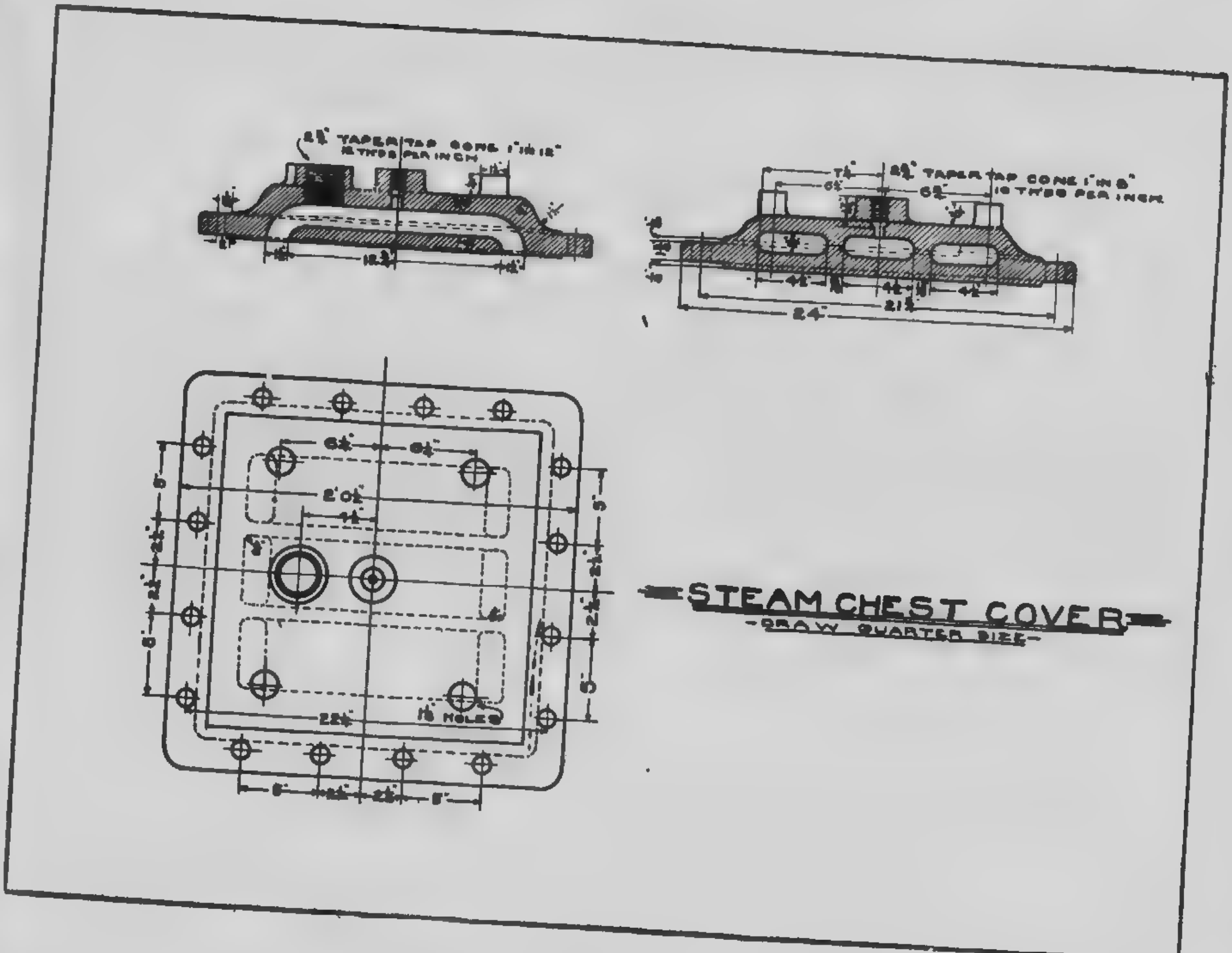
STANDARD SAND-BOX ROD AND HANDLE
DRAW FULL SIZE

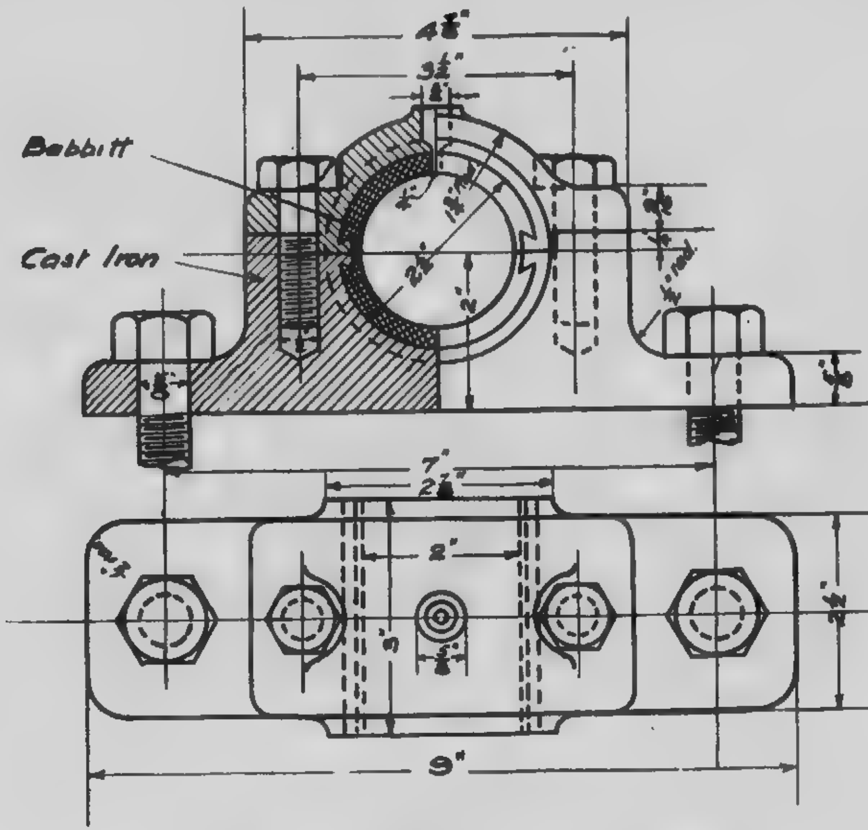
NOTE
DRAW ALL PARTS IN DETAIL SHOWING
DIMENSIONS AND TITLES


FIN.
7"
$17\frac{1}{2}$"
$24\frac{1}{2}$"
$6\frac{1}{2}$"
$\frac{7}{8}$" BOLTS
FIN. = FINISH
MAIN ENGINE TEE
DRAW HALF SIZE
CAST IRON



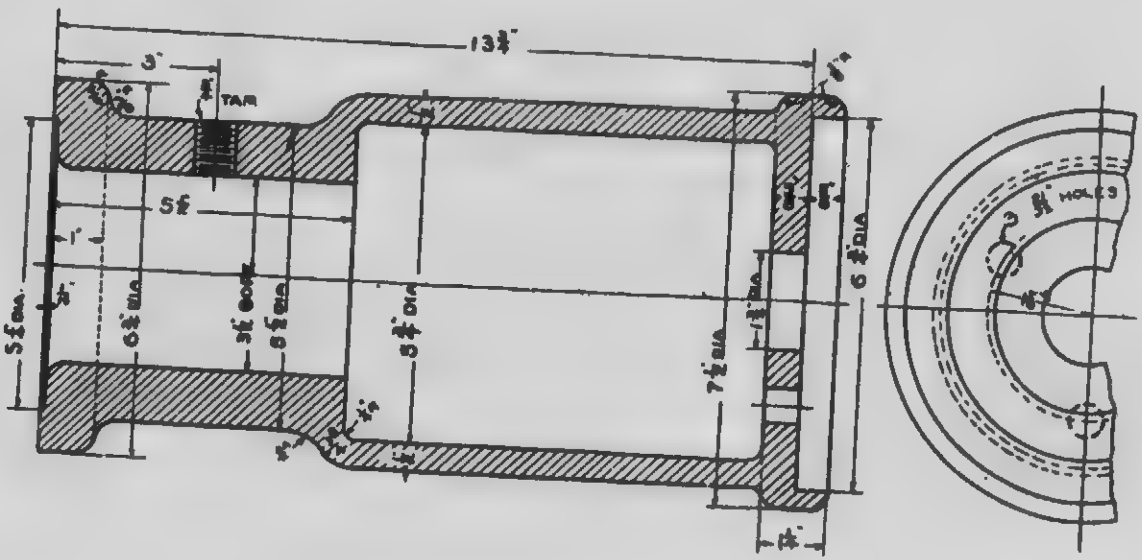
WAIST SHEET
~CROSSTIE~
~DRAW QUARTER SIZE~


STEAM CHEST COVER
DRAWN QUARTER SIZE



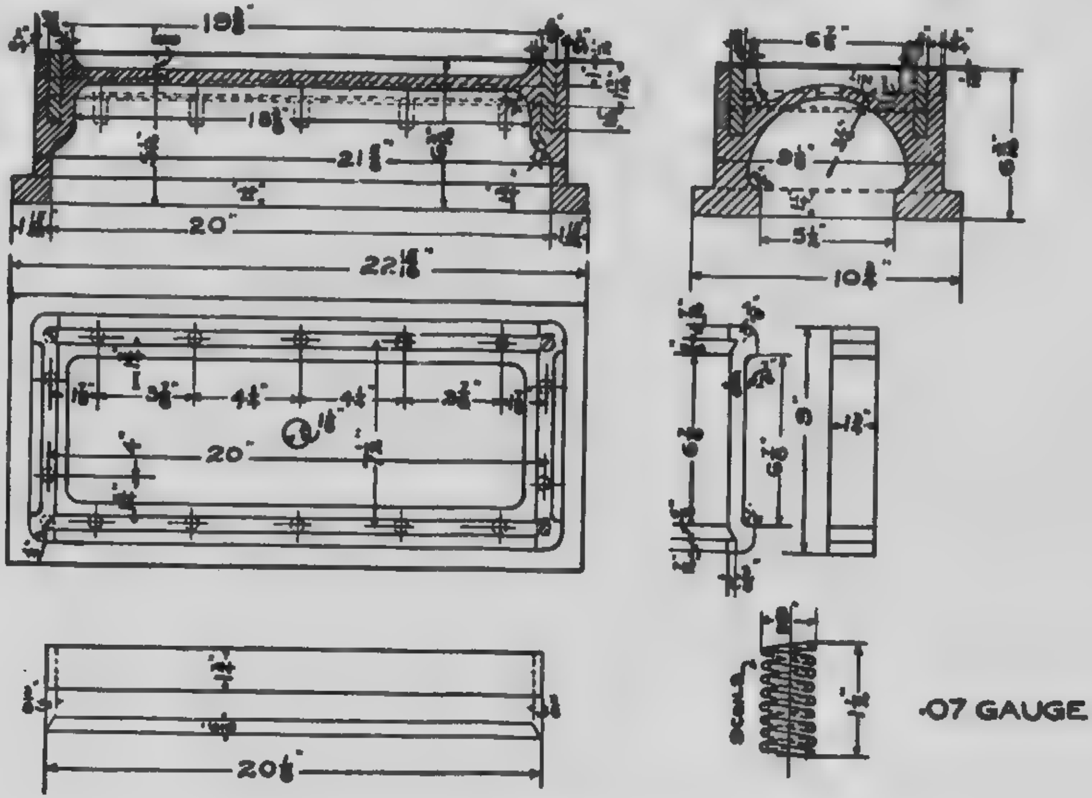
SHAFT BEARING

DRAW FULL SIZE



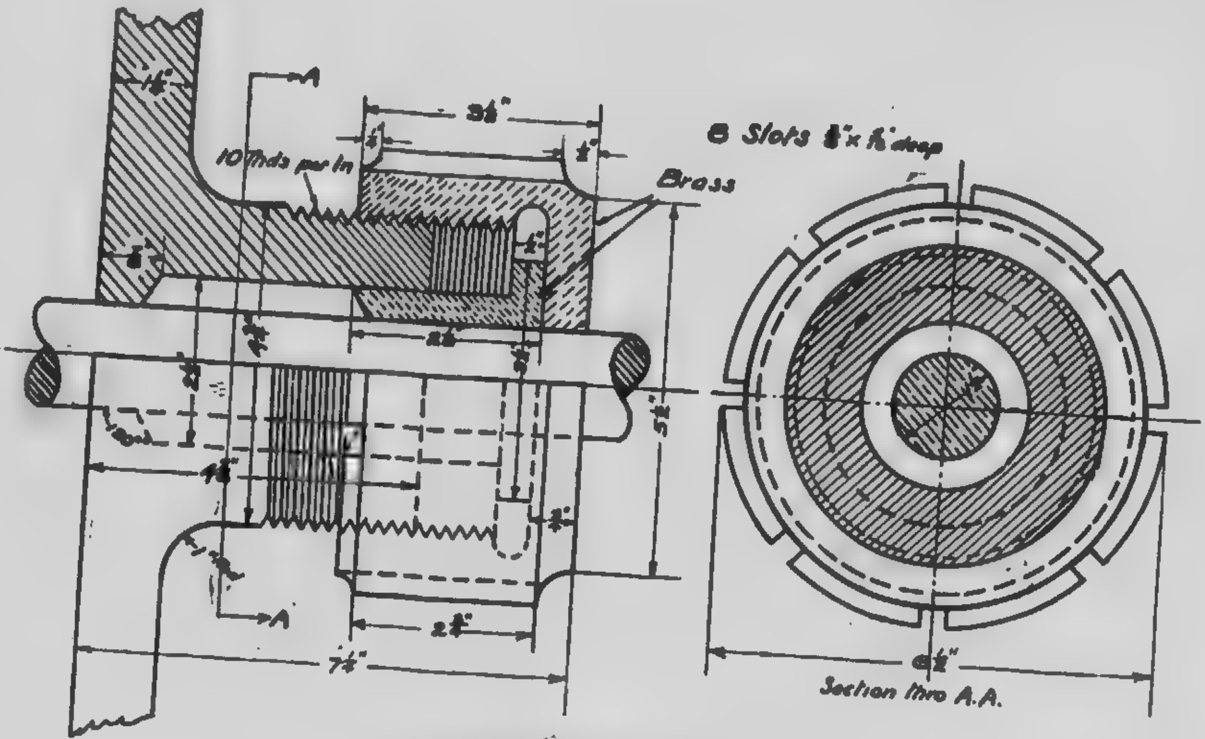
PIVOT COLUMN FOR SWING TABLE

DRAW FULL SIZE



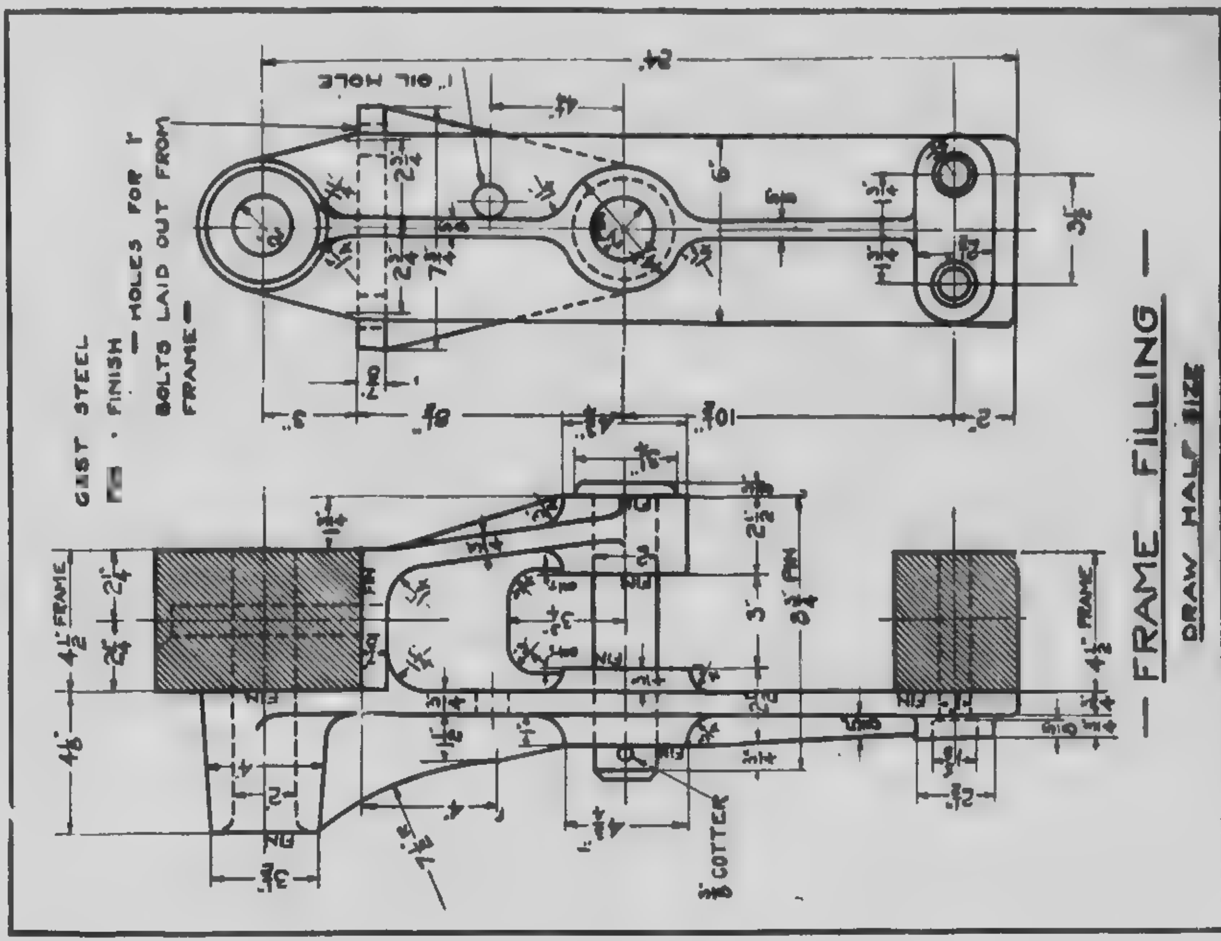
MOGUL BALANCE SLIDE VALVE

DRAW HALF SIZE

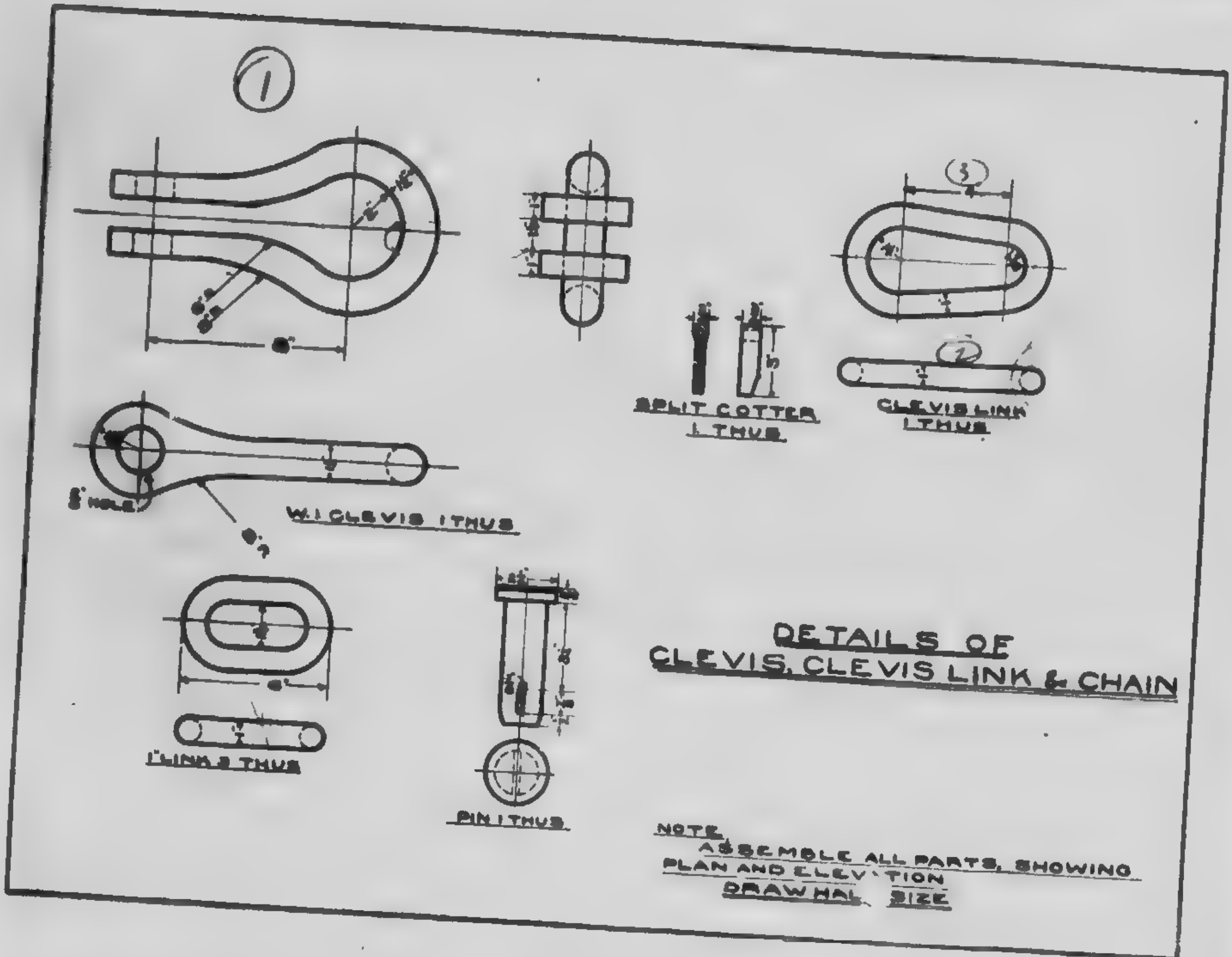


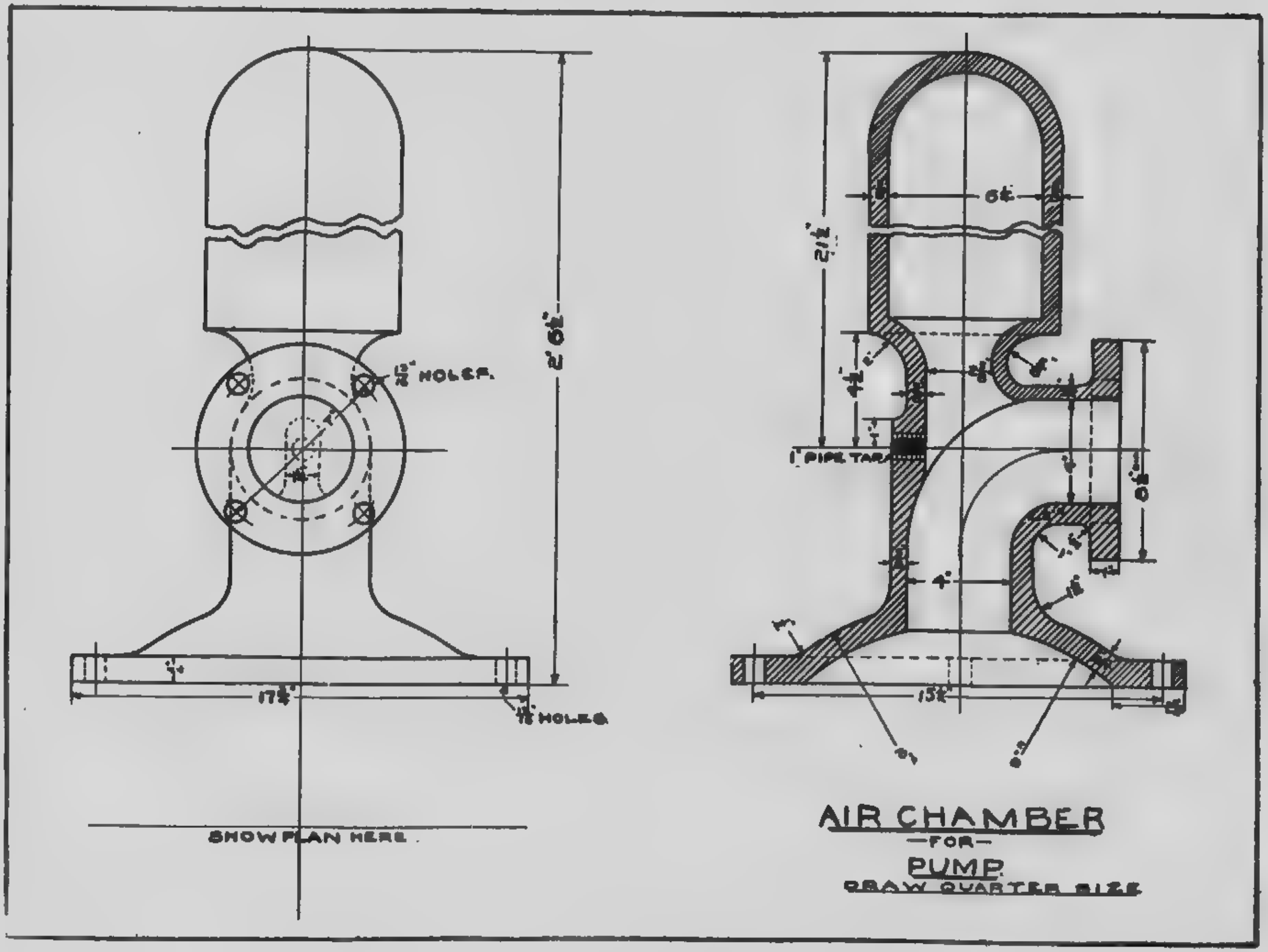
STUFFING BOX

DRAW FULL SIZE

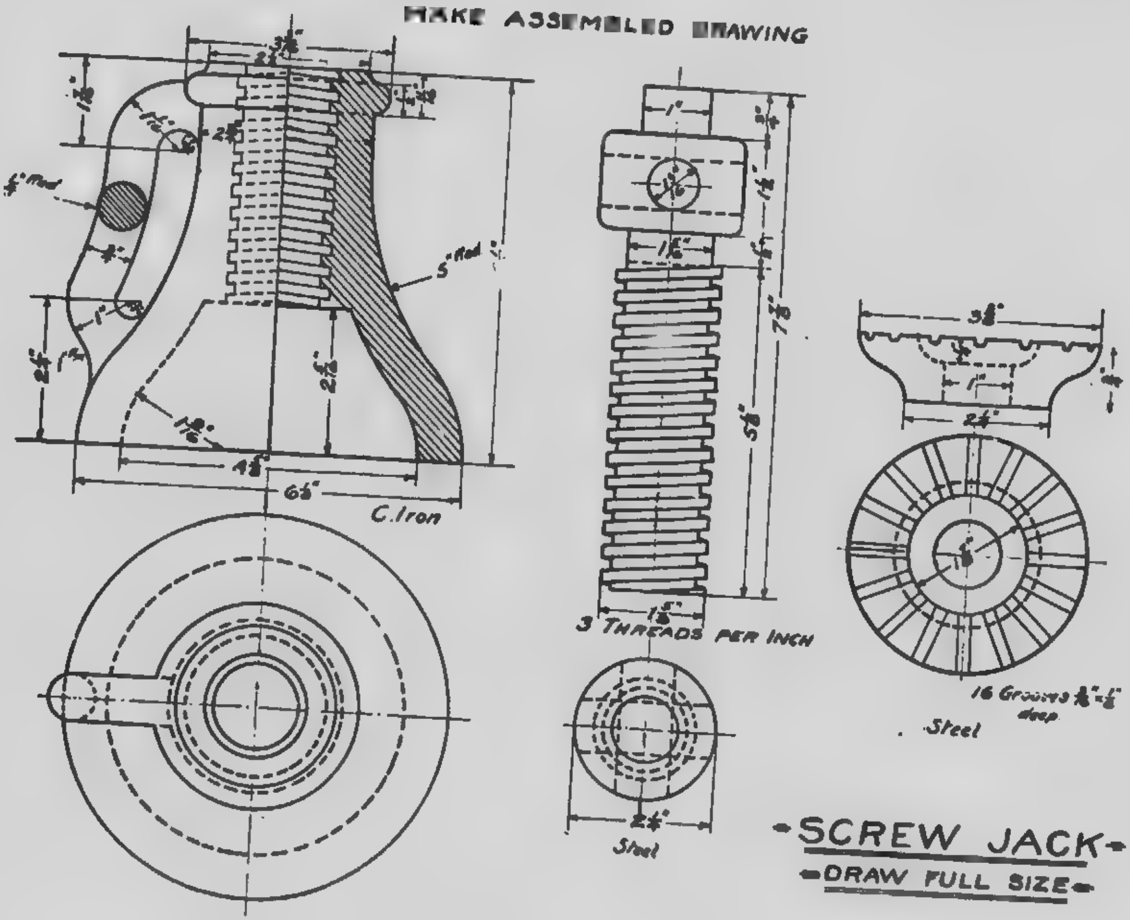


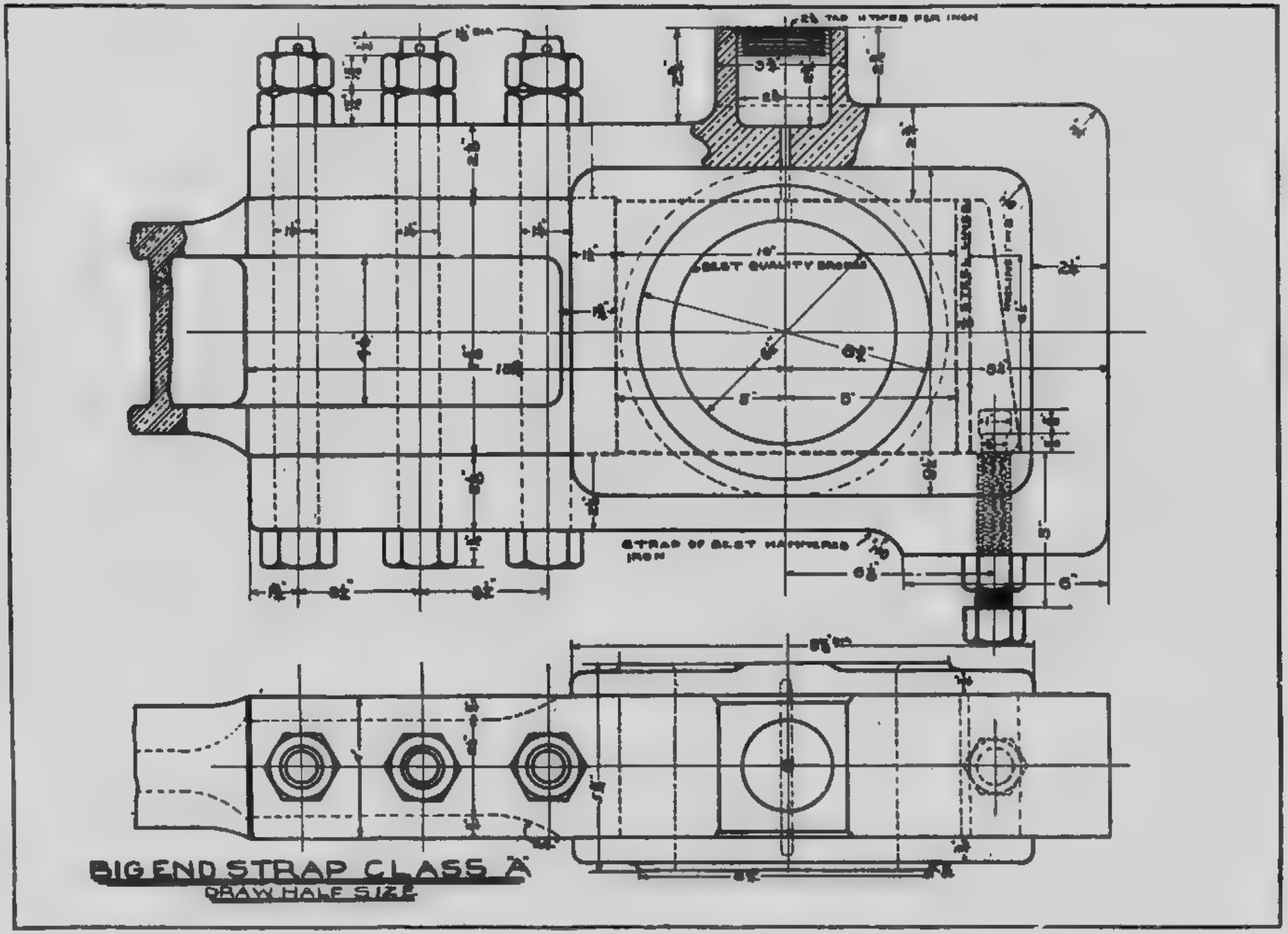
FRAME FILLING
DRAW HALF SIZE
CAST STEEL
FINISH
HOLES FOR 1" BOLTS LAID OUT FROM FRAME
1" OIL HOLE
COTTER


SPLIT COTTER
1 THUS
CLEVIS LINK
1 THUS
W.I CLEVIS 1 THUS
1" LINK 2 THUS
PIN 1 THUS
DETAILS OF
CLEVIS, CLEVIS LINK & CHAIN
NOTE.
ASSEMBLE ALL PARTS, SHOWING
PLAN AND ELEVATION
DRAW HALF SIZE

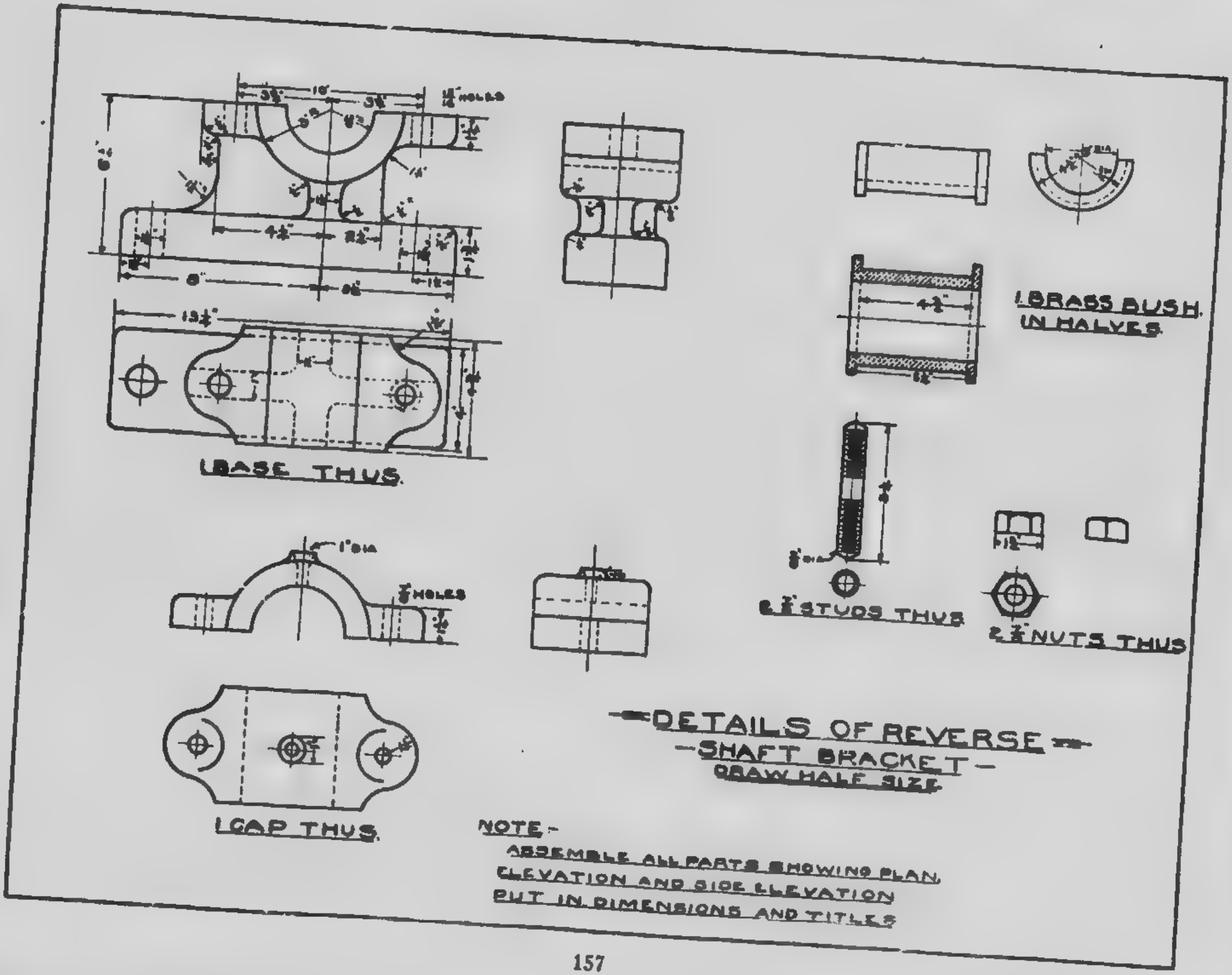


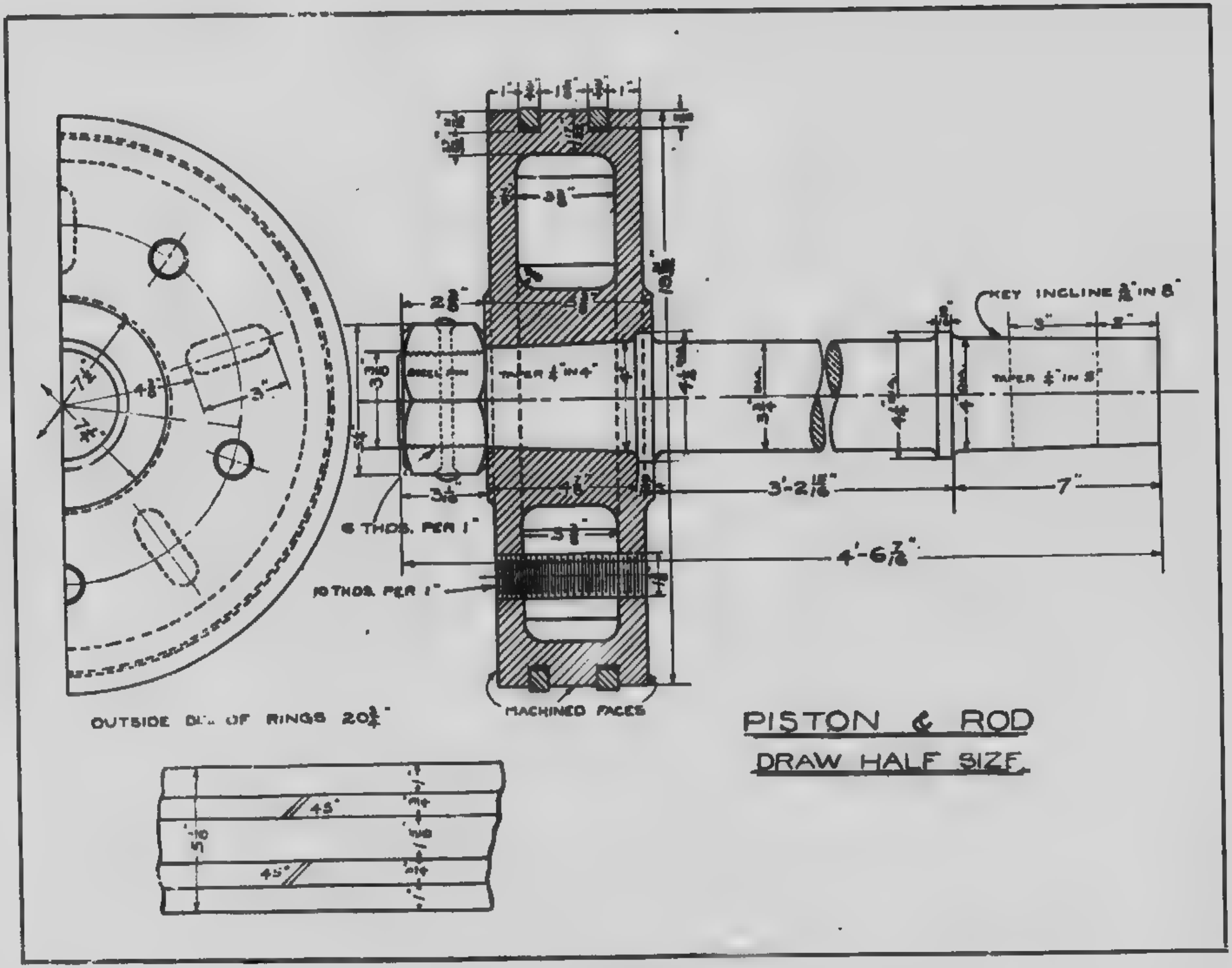
AIR CHAMBER
—FOR—
PUMP
DRAW QUARTER SIZE

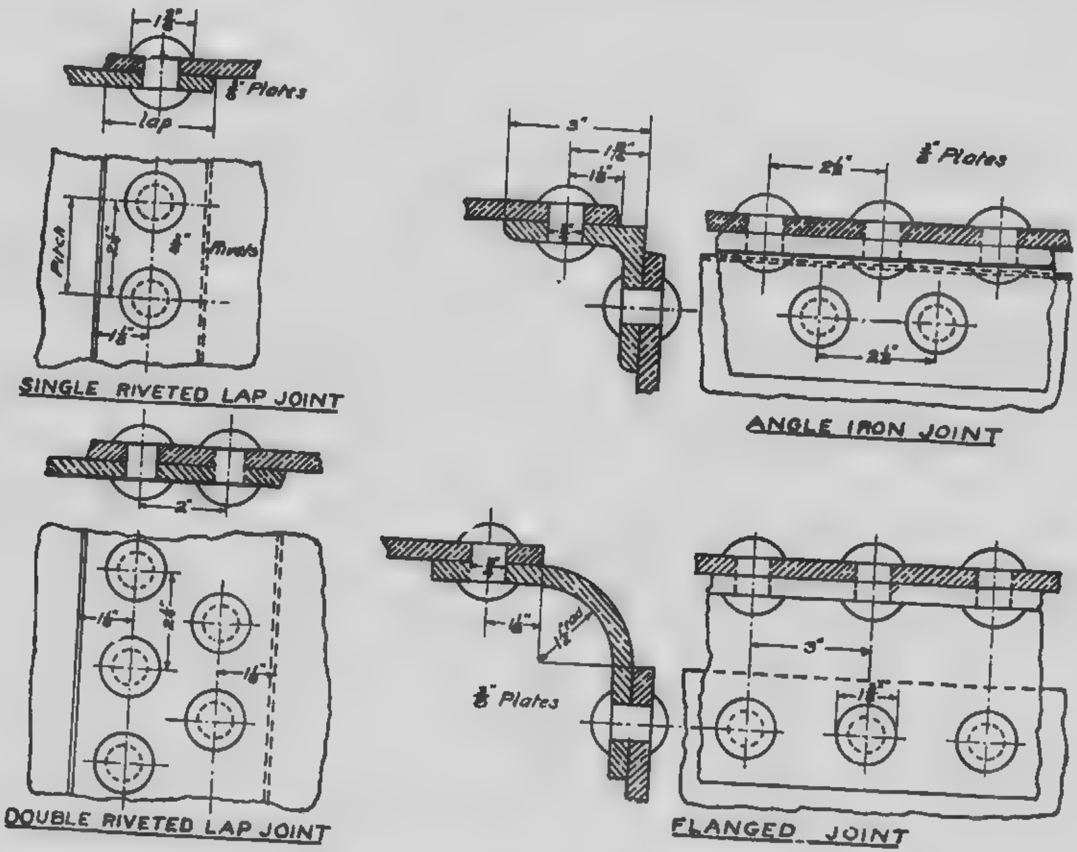

MAKE ASSEMBLED DRAWING
C. Iron
3 THREADS PER INCH
Steel
16 Grooves
deep
Steel
SCREW JACK
DRAW FULL SIZE



BIG END STRAP CLASS "A"
DRAW HALF SIZE


1 BASE THUS.
1 CAP THUS.
1 BRASS BUSH IN HALVES.
2 3/4" STUDS THUS
2 3/4" NUTS THUS
DETAILS OF REVERSE
SHAFT BRACKET
DRAW HALF SIZE.
NOTE.-
ASSEMBLE ALL PARTS SHOWING PLAN,
ELEVATION AND SIDE ELEVATION
PUT IN DIMENSIONS AND TITLES


KEY INCLINE IN 8"
TAPER IN 4"
TAPER IN 8"
STEEL PIN
6 THDS. PER 1"
10 THDS. PER 1"
3'-2 15/16"
4'-6 7/8"
7"
MACHINED FACES
OUTSIDE DIA. OF RINGS 20 1/2"
PISTON & ROD
DRAW HALF SIZE
45°
45°



—RIVETED JOINTS—
DRAW HALF SIZE

INKING DRAWINGS AND MAKING TRACINGS

Handling the Pen

In applying ink to a drawing a special form of draughtsman's pen is used that will not change the width of the line by spreading under the slight variations in hand pressure.

In general, the ruling pen and the pen point of the compass should be held in such a manner as to bring the points of both jaws on the paper at the same time. Do not lean the pen either toward the ruling edge or away from it, but hold it in a vertical plane, thus obtaining clean even lines. While the pen should not be leaned toward or away from the ruling edge, it will be found that the ink will flow more freely if the pen is leaned slightly in the direction in which the line is being drawn.

When using the compass for large circles, the legs may be bent at the hinges, so as to obtain the conditions referred to above.

Tracing

Before commencing to trace see that all the pencil lines and dimensions are drawn plainly; otherwise they may be hard to see through the tracing cloth. Place the glazed side of the tracing cloth on top, since the ink can be erased with greater ease from this side than from the dull side. It is well to rub tracing powder, or better, powdered soapstone, on the tracing cloth after it is fastened down. If these are not at hand ordinary powdered chalk will do. Great care must be exercised in keeping the drawing pens clean, otherwise the ink will not flow freely. If too much ink is put on the pen it is likely to flow too fast, and may blot. A very good habit to acquire is to wipe out the pen each time fresh ink is to be put in; by doing this fine lines can be drawn more easily.

In deciding on the width of line, the student should bear in mind that to get blue prints with clear white lines, it is necessary that the lines of the tracing be fairly heavy, not the fine, "pretty" lines that beginners are so apt to use.

In tracing it is well to observe the following:

(1) Ink in all arcs and circles first, because it is easier to join them with a straight line than it is to connect two straight lines with an arc.

(2) Beginning at the top, rule in all horizontal outlines; next, starting at the left side, rule in all vertical outlines; and, finally, rule in the angular outlines.

(3) Adjusting the pen to a much finer line, rule in the projection lines.

(4) Rule in the dimension lines; these lines for drawings of small figures should be solid, except for the opening left for the dimension lines; then put in dimensions, using care to make the figures clear.

(5) Do all cross-sectioning after the main lines of the object and all dimensions and dimension lines are put in.

(6) In making straight lines be careful so that the point of the pen will not touch the lower edge of the square or triangle, according to which is used. The pen should be held inclining slightly in the direction in which the line is to be drawn.

At times it may be necessary to ink a drawing instead of tracing it; in doing this, the same precautions must be followed as in making a drawing on tracing cloth.

Finished Drawing

In the finished drawing there should be a marked contrast between the weight of the outlines of the figure, and of the centre, projection, and dimension lines; the latter should be decidedly lighter than the outlines. When these various lines are drawn to the proper proportions and are well arranged, the figure seems to stand out by itself and is much more easily understood.

When the drawing is completed, print the title on neatly and carefully, as the looks of a good drawing will be spoiled if the printing is done in a careless, slipshod manner.

Select a medium-point pen for lettering and making arrow-heads.

Blueprinting

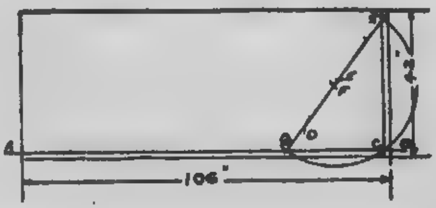
Blueprint paper is a white paper, one side of which has a coating sensitive to light; so long as the paper is protected from light the coating can be easily removed by washing, but on exposure to sunlight, the coating turns blue, and turns a deep blue when placed in water.

A print is obtained by means of a wooden frame with a glass, and having a removable back lined with woollen felt. The tracing is placed with the ink lines next to the glass; the blueprint paper with the sensitized surface next to the tracing. The felt is then placed over these and the cover fastened down, being careful that the tracing and blueprint paper are in close contact, as otherwise more or less light will pass underneath the ink lines and make a poor print. On exposing the frame to direct sunlight, the light passes through the tracing cloth not covered with ink lines and acts on the sensitized surface, while the portions of this surface protected by the lines of the tracing are not affected. After an exposure of from twenty seconds to five minutes, depending on the "speed" of the paper and the brightness of the sunlight, the print is washed in a tank. After washing, the print must be hung up that it may drain properly and dry flat. A good print shows clear white lines on a uniform blue ground.

Special care must be taken to exclude light from blueprint paper. It may be kept in a can painted black on the inside and outside, and should be removed from this only in subdued light, or preferably in a dark room.

THE PRACTICAL APPLICATION OF GEOMETRY TO SOME SHOP PROBLEMS IN LAYING-OUT

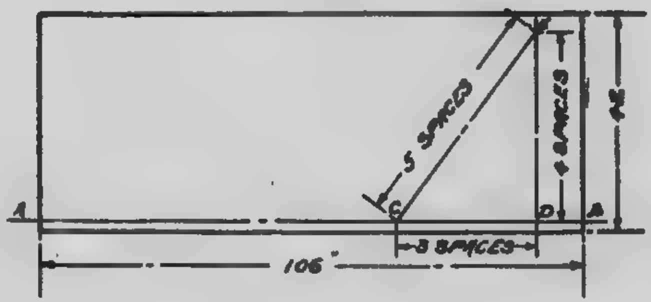
To Square a Tank Sheet



In drawing this lesson do not use T-square or triangles.

Making use of the above method for erecting a perpendicular, square up a tank sheet 42" by 106". Scale: ¼" equals 1'.

Second Method

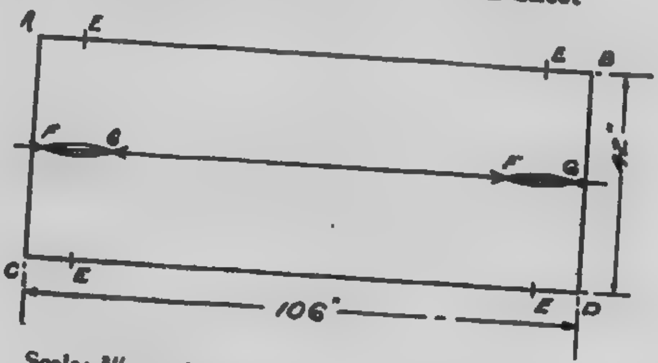


Scale: ⅜" equals 1'.

With any convenient distance as one space, step off CD equal to three spaces. With radius equal to five spaces and C as centre draw arc at E.

With radius equal to four spaces and D as centre describe arc at E. A line drawn through D and E will be perpendicular to AB. Do not use T-square. Do not use triangles.

To Find the Centre Line of a Tank Sheet



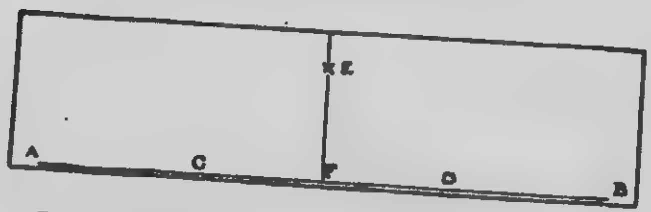
Scale: $\frac{3}{8}''$ equals 1′.

Square up a tank sheet to the size shown.

Locate points E equidistant from A, B, C and D. With radius equal to more than half the distance between B and F and G. A line drawn through these points with a straight edge will be the centre line.

Do not use T-square in squaring up this sheet.

To Square a Smokebox Sheet



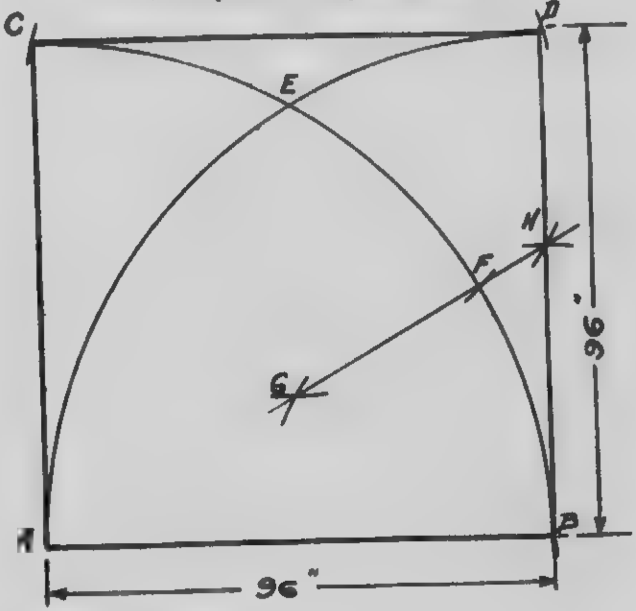
Scale: $\frac{3}{8}''$ equals 1′.

Do not use T-square.

Draw a rectangular smokebox sheet approximately $53\frac{1}{4}'' \times 236''$.

Draw line AB with straight edge. With point F on line AB as a centre and with any radius draw arcs at C and D. With C and D as centres and with a greater radius than CF describe two intersecting arcs at E. A line drawn through E and F will be perpendicular to AB at F.

To Lay Out a Square Sheet

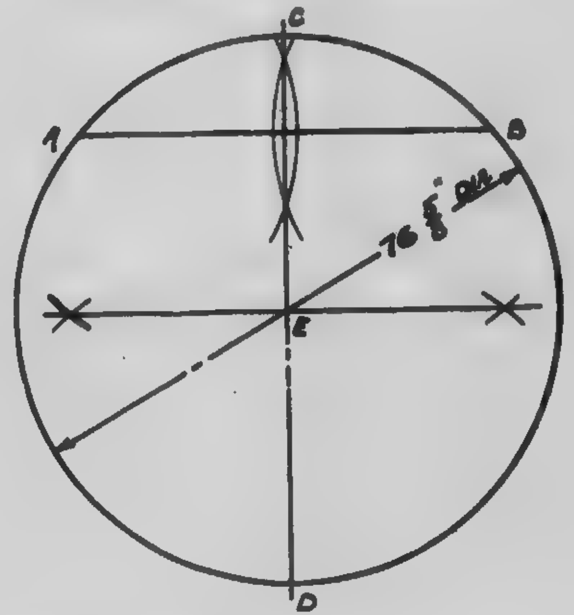


Scale: $\frac{3}{4}$″ equals 1′.

Do not use T-square.

With a radius equal to AB and with centres at A and B draw arcs BC and AD intersecting at E. With a radius equal to more than half the arc EB and with centres at E and B describe arcs intersecting at C and H. Draw a line through these two points intersecting arc EB at F. With E as a centre and a radius equal to EF describe arcs intersecting BC and AD at C and D. Joining these points of intersection, ABCD will be a perfect square.

To Find the Centre of a Flue Sheet



Scale: $\frac{3}{4}$″ equals 1′.

Do not use T-square.

Draw chord AB. Erect a perpendicular CD at the centre of AB, which will also be a diameter of the flue sheet. Erect a perpendicular at the centre of CD. Their intersection at E will be centre of the flue sheet.

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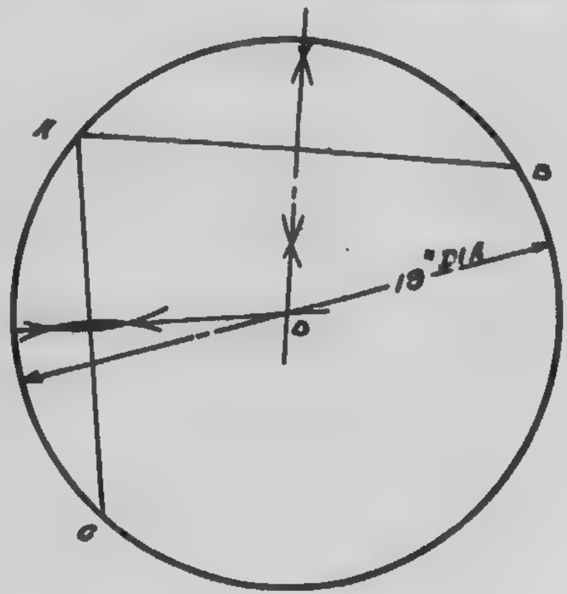
To Find the Centre of an Air Drum Head



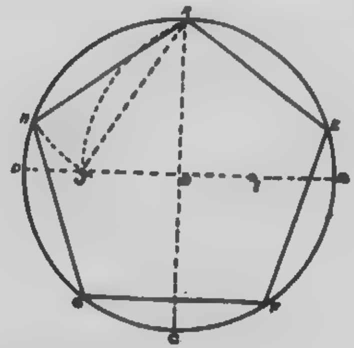
Scale: 3″ equals 1′.

Do not use T-square.

Draw chords AB and AC intersecting on the circumference at A. The intersection of perpendiculars erected at the centre of these two chords will be the centre of the air drum head.

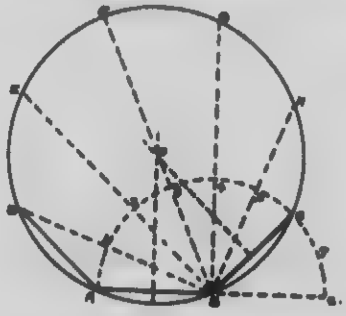
ADVANCED GEOMETRICAL PROBLEMS

To Inscribe a Pentagon



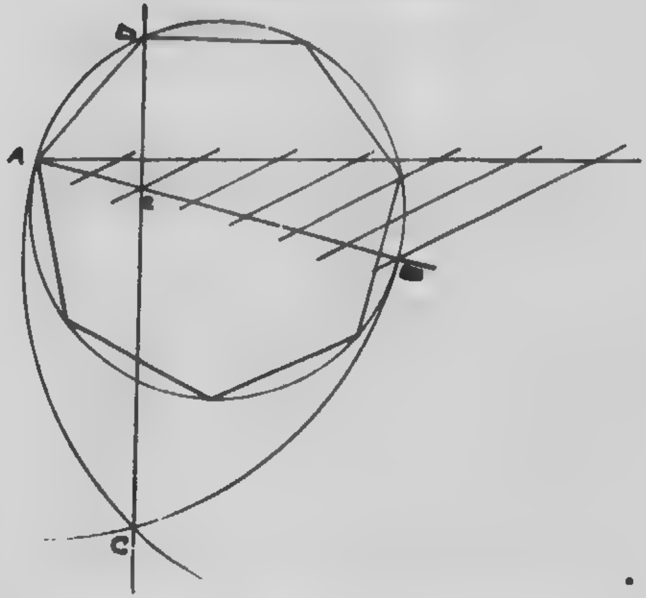
Let I bisect OB. Use IA as a radius and scribe arc AJ. With A as a centre scribe arc JH. AH is one side of the required pentagon. Using same method draw decagon, that is, a ten-sided figure, bisecting each side and the arc it subtends.

Given One Side to Construct a Polygon



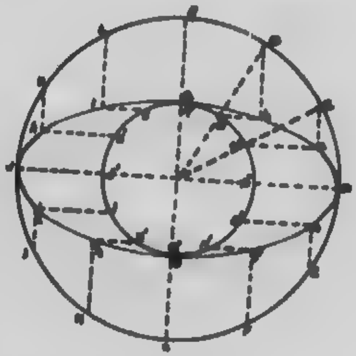
Let AB equal the length of the given side, and extend to C, making BC equal to AB. Draw a semicircle on ABD and divide it into as many parts as the polygon is to have sides and number of parts. From B to a point two spaces away from C draw B6. Locate point O centre of a circle through A, B and 6. Draw line through B and A, 2, 3, 4, 5, to meet the circle. Draw AD, etc., the sides of the required polygon.

To Inscribe any Polygon



Divide the diameter of the circle into as many equal parts as there are sides on the polygon required. With A and then B as centres and radius AB cross arcs at C. Join C to the second division and extend the line until it cuts the circumference at D. Join AD, which will be one side of the required polygon. Lay off the remaining sides equal to AD.

To Construct an Ellipse



Divide the two concentric circles proportionately into any number of parts.

Project B^1, C^1, etc., horizontally to meet B, C, etc., projected vertically. Put in the curve through the points thus formed with the irregular curve.

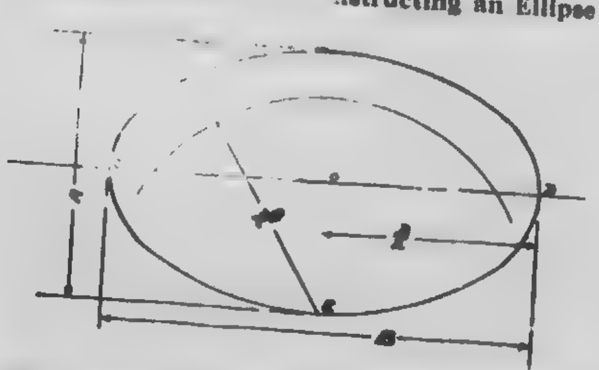
A line drawn lengthwise through the centre of the ellipse JD is called the major axis.

The shortest diameter "ag" is called the minor axis.

Note.—The irregular curve referred to in the above is a form of template used by draughtsmen for drawing irregularly curved lines, the location of which have been previously plotted by means of a series of points.

Arrange the previous four problems on a standard drawing sheet.

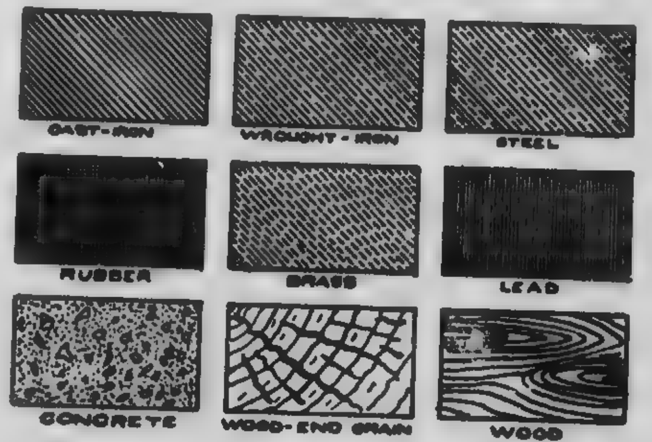
A Practical Method of Constructing an Ellipse



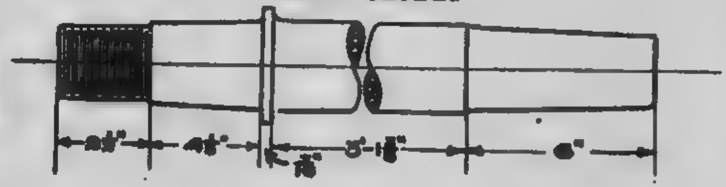
When convenient, an ellipse may be drawn by means of a string and three pins. Lay off the two axes CD and OE and lay off on them the desired length B and width A. With point E as a centre, using a radius equal to one-half of B, describe an arc cutting the major (long) axis in two points. Drive pins at each of these points and at E. Tie a string snugly around the three pins and take out the pin at E. Draw the slack taut with a pencil point and run the pencil around the slack of the string and it will describe a perfect ellipse.

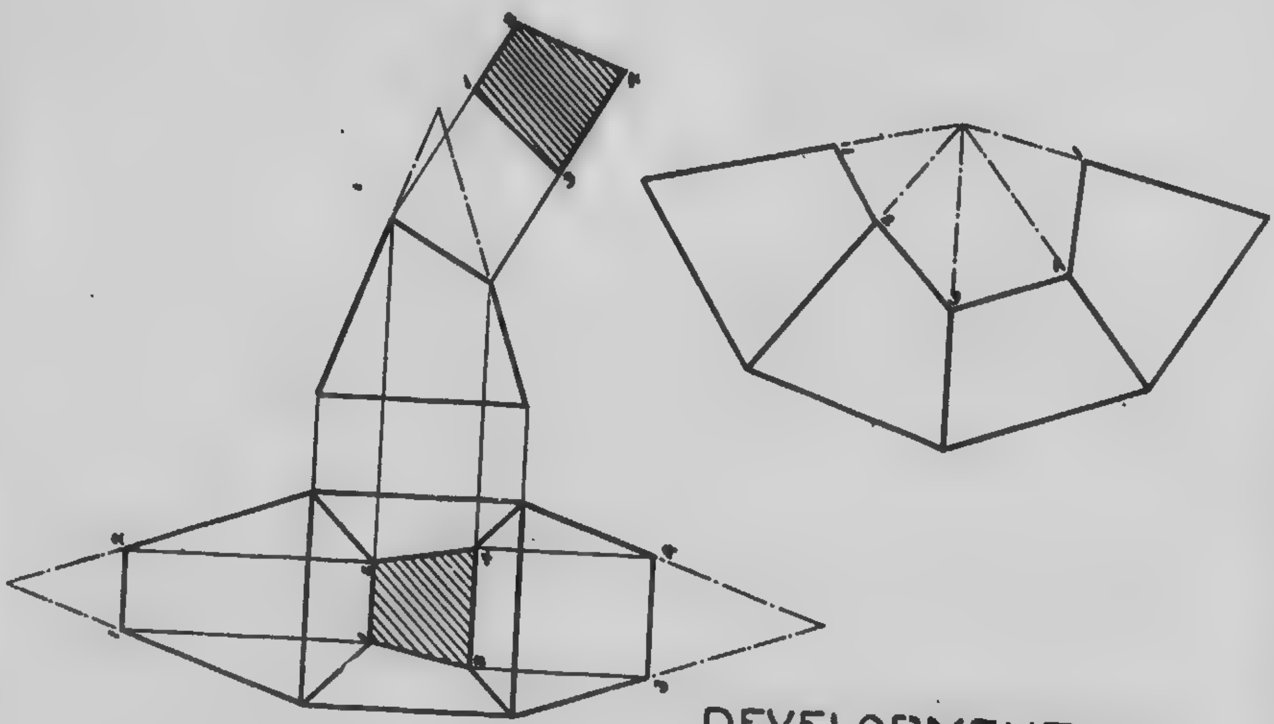
Exercise. Practise the above construction several times, drawing a different-sized ellipse each time.

VARIOUS STYLES OF CROSS-HATCHING

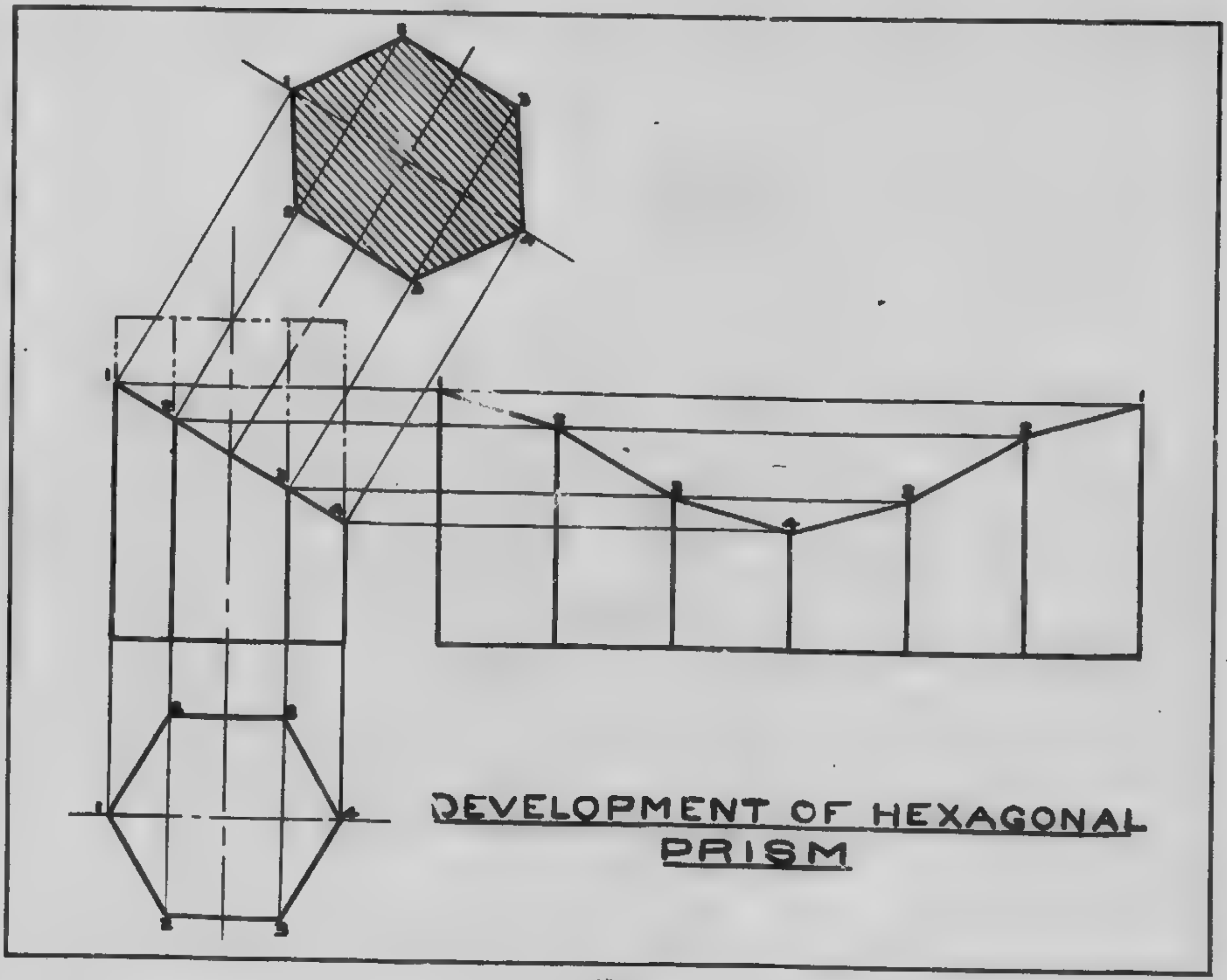


METHOD OF SHORTENING UP A VIEW OF AN OBJECT

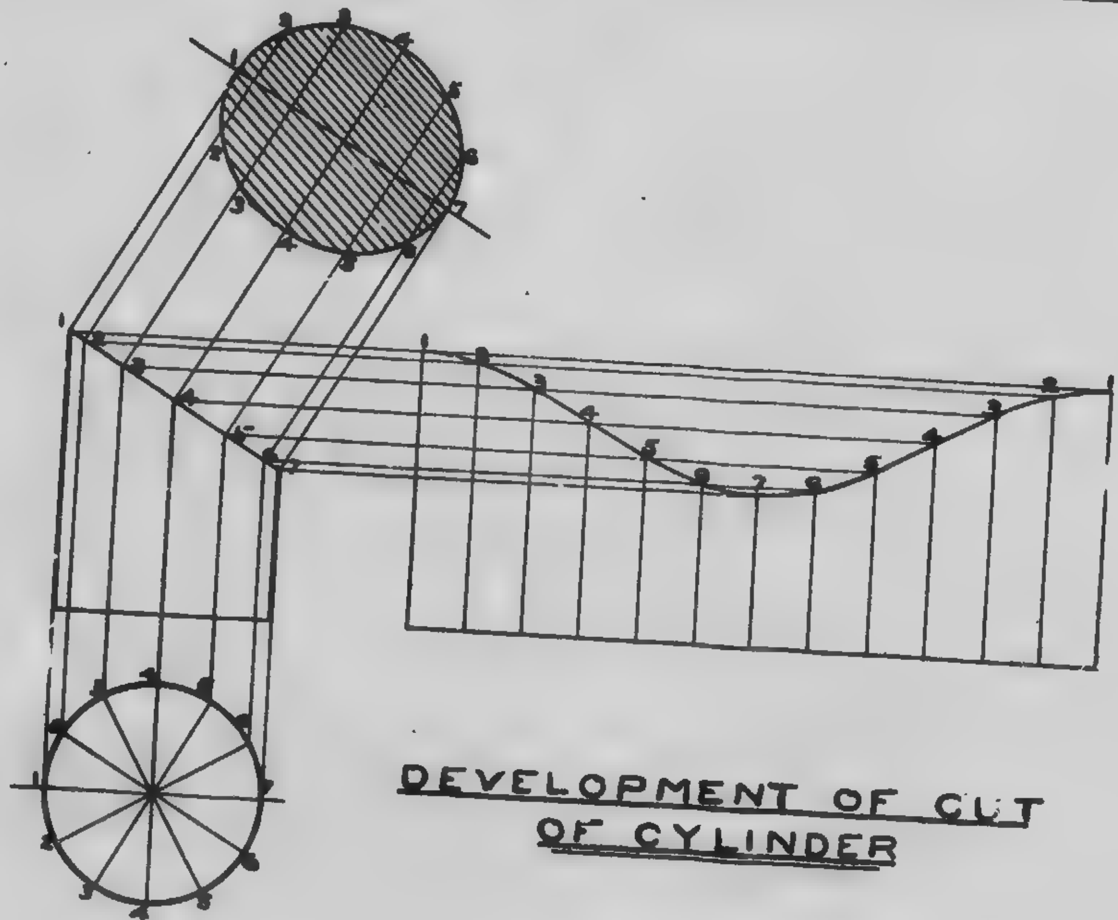




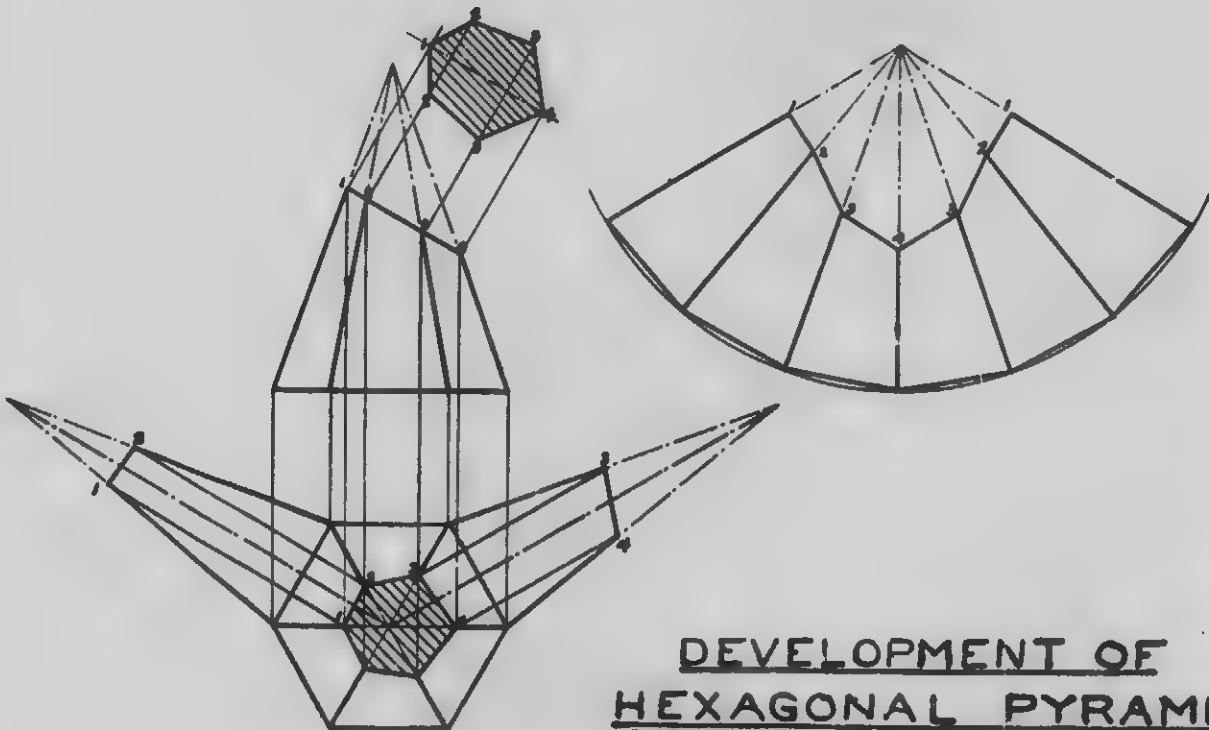
DEVELOPMENT OF PYRAMID



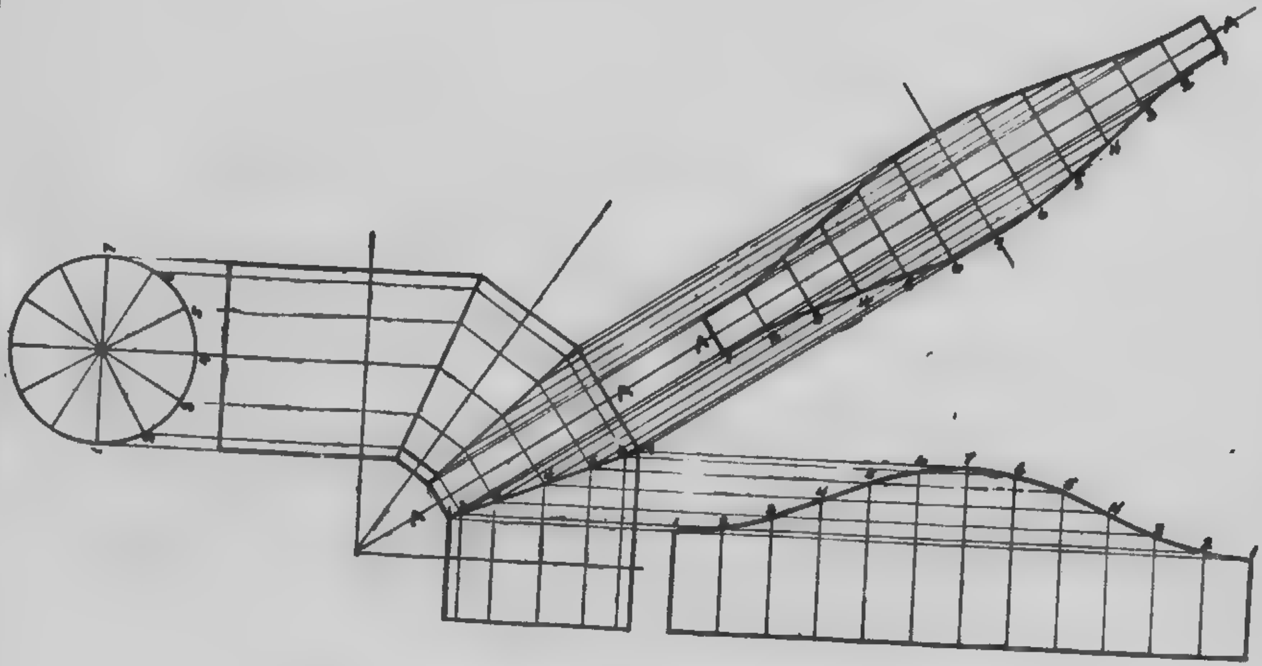
DEVELOPMENT OF HEXAGONAL PRISM



DEVELOPMENT OF CUT OF CYLINDER



DEVELOPMENT OF HEXAGONAL PYRAMID



DEVELOPMENT OF ELBOW

THE SQUARE THREAD

In practice, the square thread is used where it is found necessary to obtain a quick travel or LEAD. It is used for transmitting motion and regulating the position of slides or other machine parts.

The PITCH of a square thread is exactly the same as the pitch in the V thread, i.e., the distance from a point on one thread to a similar point on the adjacent thread (parallel with the centre line).

The LEAD (a term generally used when referring to multiple threads) is the distance from a point on one thread to a similar point on the same thread after this thread has made one turn around the screw; thus, in a single threaded screw the lead would be equal to the pitch; in a double threaded screw the lead would be equal to twice the pitch; in a triple threaded screw the lead would be equal to three times the pitch; and in the quadruple threaded screw the lead would be equal to four times the pitch.

The depth of the thread and the width of the same are usually made equal to one-half the pitch; thus, with a half-inch pitch the depth would be one-quarter inch, and the width would also be one-quarter-inch.

The number of square threads per inch is usually taken at one-half that of the angular threads per inch; take, for example, a 1" V standard screw, the number of threads per inch would equal 8; in a square threaded screw of the same diameter the number of threads per inch would equal 4.

In drawing square threaded screws, the correct method is seldom used, as it would require too much time to lay out and draw the curves; therefore a conventional method, in which straight lines only are used, is employed and used almost universally. Both methods will be taken up by the student and are illustrated here.

To draw the square threaded screw (single) **CONVENTIONAL METHOD Right Hand Screw:**

Proceed as follows:—First locate and draw centre line, then draw fine lines to this, as UV, WX; these lines represent the outside diameter and the root diameter of the thread. At right angles to these lines draw fine parallel lines, AB, CD, EF, etc., the distance between these lines to be equal to one-half the pitch; now (using your two set-squares) connect points B and C, D and E, and so on until the required number of threads is obtained. The distance P equals the pitch (also the lead in this case); therefore, point B, in making one complete turn, would move along the screw a distance equal to B, F, or P, as clearly shown by the full line BC and full and dotted line CF. The dotted lines are not to be shown on the drawing; they are used here to make it clear to the student how the full part of the lines AD, CF and EH is obtained. Now, while the thread is parallel throughout its depth, on account of winding around and at the same time moving along the body, two lines are seen at certain places, by following the full and dotted lines 1, 2, 3, 4 on this Plate the student should have no difficulty in locating same. Remember that the dotted lines are not to be shown. Have all your work done in fine lines, and when you have construction complete and correct, go over same and make the required thickness, omitting the unseen lines, which may then be easily removed by the eraser.

Left Hand Screw:

Reverse above layout.

To draw the square threaded screw. Correct Method:

Before commencing to draw the Plate, the student must clearly understand and be able to draw a Helix. The Helix is a curve formed by a point moving around a cylinder and at the same time advancing along its length.

To draw a Helix:

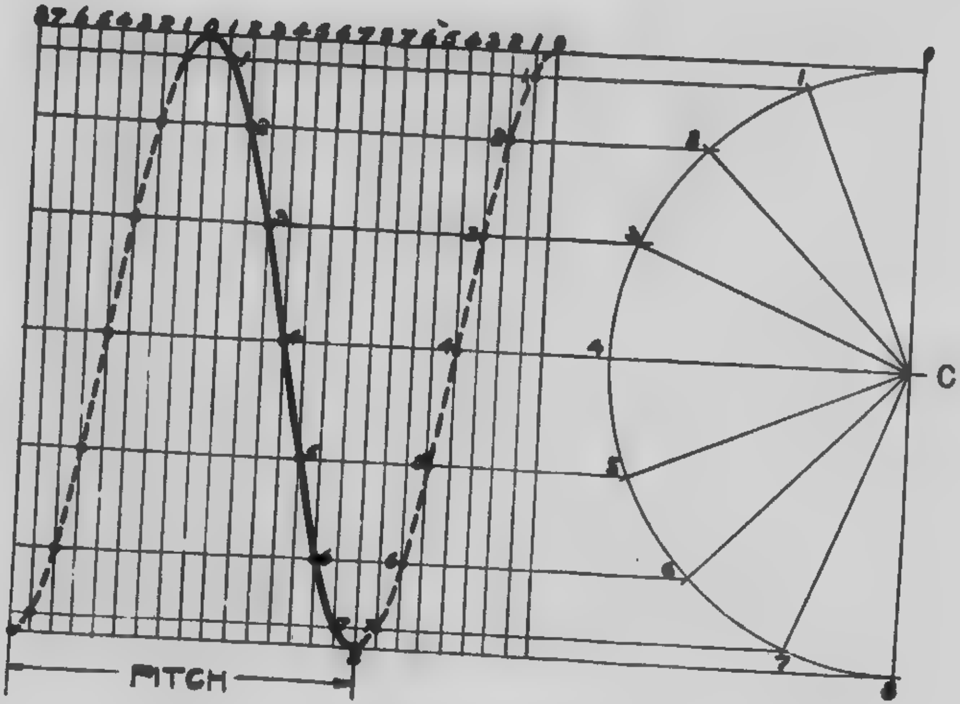
The diameter of the cylinder is 3½". The pitch (the distance that a point will move along in making one complete revolution) is 2".

After locating the centre lines, draw the semicircle 3" in diameter, and divide this semicircle into any number of equal parts (8 is shown on Plate), draw lines C1, C2, etc., number these points as shown; now project over the lines from these points parallel to centre line. At right angles to centre line draw the parallel lines 0-0′, 1-1′, etc.; the distance between these lines will be equal to the pitch divided by twice the number of parts into which the semicircle has been divided, thus, 2÷16=⅛"; number these parts and plot points as shown, then by using the irregular curve or French curve, draw a curve passing through these points. This curve is called a Helix.

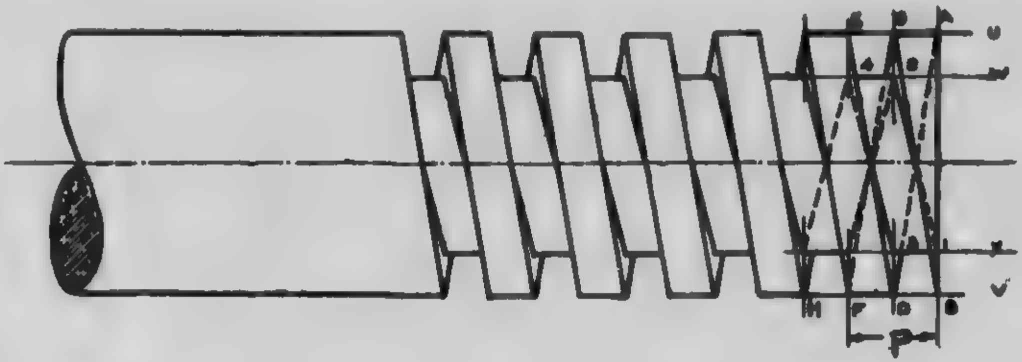
By carefully studying the correct method of single threads, the student will note that the outline of the thread is simply, first, a helix wound around a cylinder whose diameter is equal to the outside diameter of thread; second, a helix wound around a cylinder whose diameter is equal to the root diameter of thread; the pitch in both cases being equal to the lead of the screw, and the distance between the starting point of each helix is equal to half the pitch.

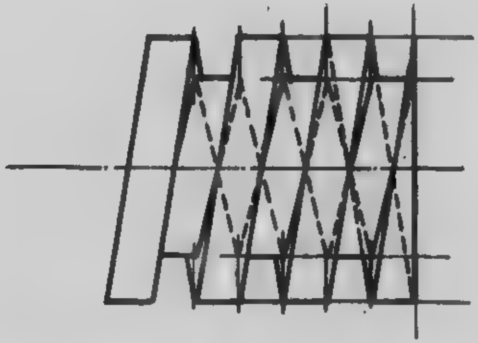
To draw a single thread (correct method), draw semicircles 1¼" diameter and 1" diameter, and divide same into four equal parts; project over lines from points 1-2-3 and 4 parallel to the centre line. Divide the lead (which in the case of this single thread is also the pitch) into eight equal parts and plot the curve. Remember that the dotted line is not required to be shown; it is used here in order that the curve may be clearly traced by the student. Points 4 O A are the first half-turn of the thread. Starting from point 4, the helix representing the outside diameter is seen until it passes behind the body of the screw; it again comes into view at point F. Remembering that the pitch is ½", and that the width of the thread equals ½ the pitch, four points away from A at point B (the distance of ¼") the next helix is started; after completing the first curve the student is advised to cut a templet of same (using fine cardboard or bristol board for this purpose). Any required number of threads may now easily be laid off. After completing the curves representing the outside outline of the threads, commencing at point C, plot and draw the small curve representing the root of the thread on the body of the screw; it will be noticed that this curve only comes into view on reaching the centre line, and disappears over the body. Four points from C the next small helix is started, and this curve remains in view until the centre is reached, when it also disappears behind the second thread.

By carefully studying the Plate, the student should not find any difficulty in tracing the curves. Any multiple thread, double, triple, etc., is drawn in the same manner.



HELIX

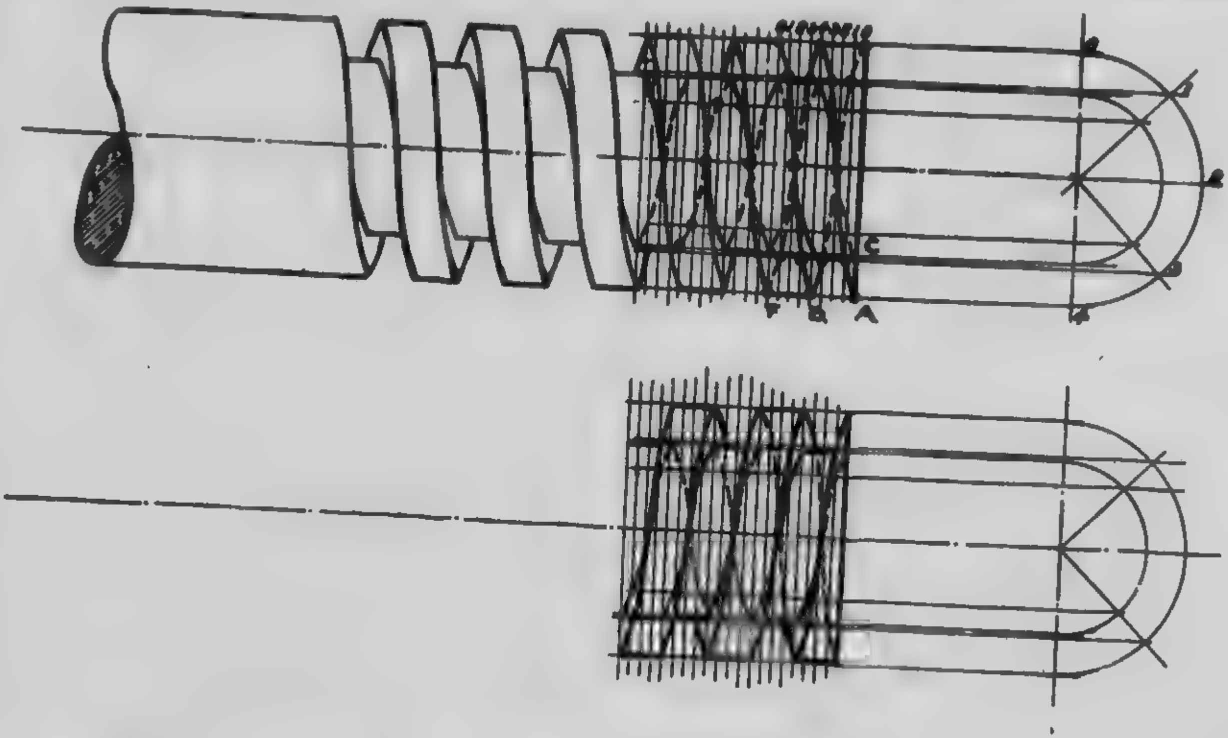




RIGHT AND LEFT HAND SQ THREAD

SINGLE

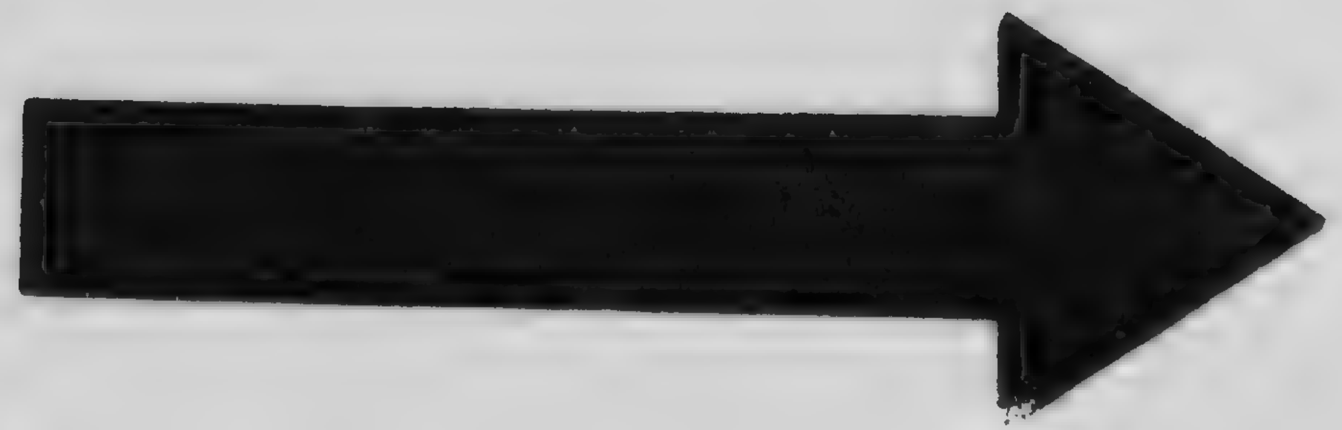
CONVENTIONAL METHOD



RIGHT AND LEFT HAND SQ THREAD

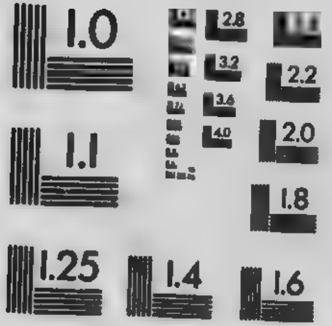
SINGLE

CORRECT METHOD



MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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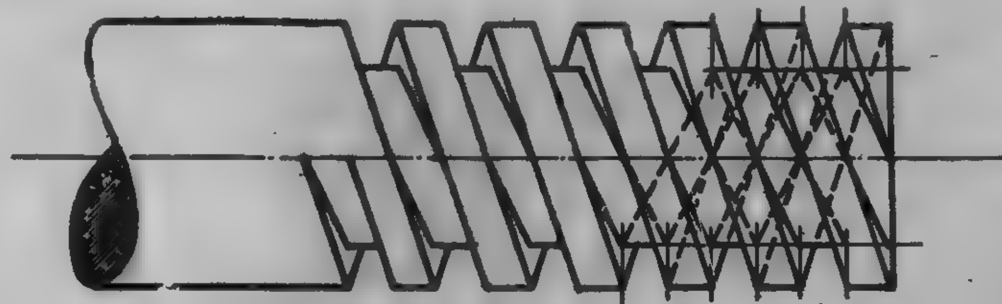
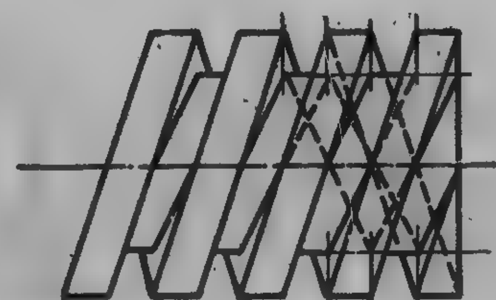
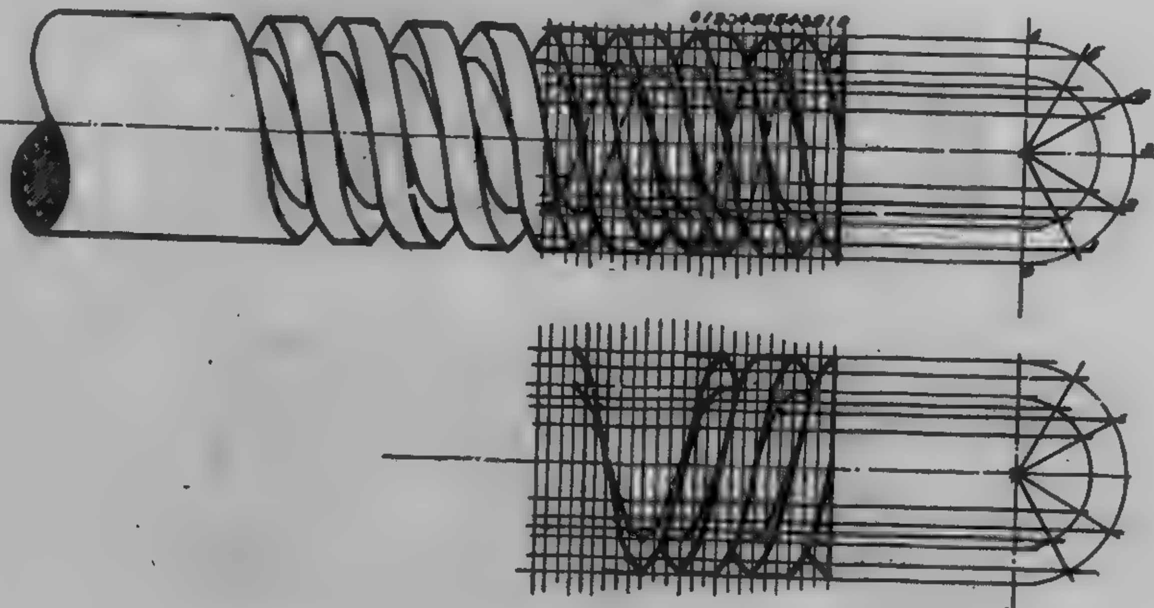




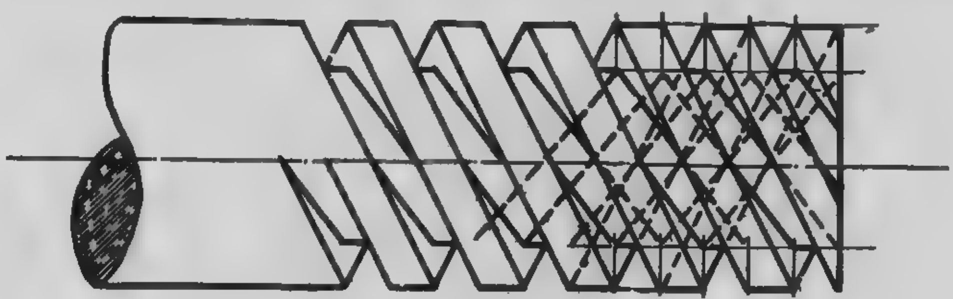
RIGHT AND LEFT HAND SQ THREAD

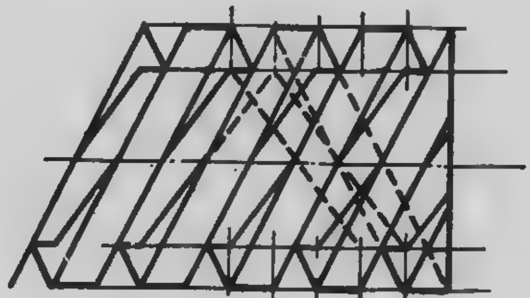
DOUBLE

CONVENTIONAL METHOD



RIGHT AND LEFT HAND SQ THREAD
DOUBLE
CORRECT METHOD

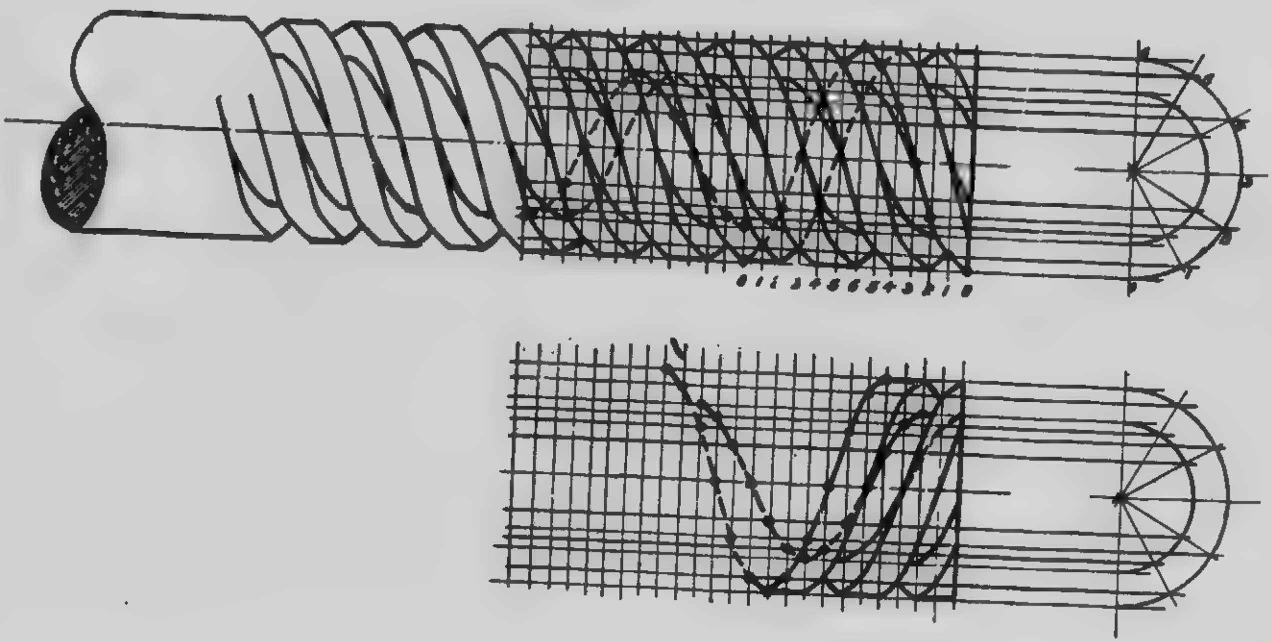




RIGHT AND LEFT HAND SQ THREAD

TRIPLE

CONVENTIONAL METHOD



RIGHT AND LEFT HAND SQ THREAD

TRIPLE

CORRECT METHOD

DATA SHEET

BOILER TUBE DATA

A	B	C	D	E	G
1½"	.393	1.767	.095" .109"	.419 .480	13 12
1¾"	.458	2.405	.095" .109"	.494 .566	13 12
2 "	.524	3.142	.095" .109" .12 "	.589 .654 .709	13 12 11
2¼"	.589	3.976	.095" .109" .12 "	.643 .739 .803	13 12 11

TABLE No. 1

A = Outside diameter.
B = Square feet of heating surface per foot of length.
C = Area of section in square inches.
D = Thickness of tube in inches.
E = Area of metal in square inches.
G = Birmingham wire gauge.

ANGLE IRON DATA

A	B	C	D	E
1 "	1 "	9/16"	¼"	⅛"
1¼"	1¼"	11/16"	¼"	3/16"
1½"	1½"	13/16"	5/16"	¼"
1¾"	1¾"	1 "	⅜"	¼"
2 "	2 "	1⅛"	½"	¼"
2¼"	2¼"	1¼"	⅝"	¼"
2½"	2½"	1⅜"	⅝"	⅜"
2¾"	2¾"	1 9/16"	¾"	½"
3 "	3 "	1¾"	¾"	⅝"
3½"	3½"	2 "	¾"	¾"

TABLE No. 2

DATA SHEET

PIPE THREAD DATA

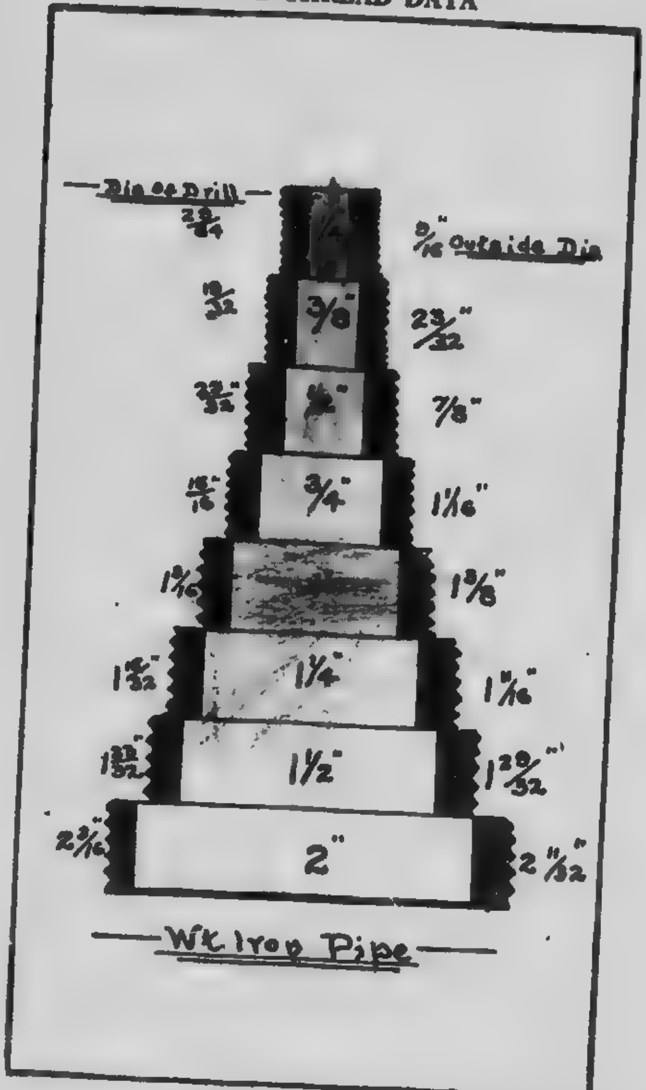


TABLE No. 3

STANDARD WROUGHT-IRON WELDED TUBES

Diameter of Tube			Thickness of Metal	Screwed Ends	
Nominal inside	Actual inside	Actual outside		No. of Threads per inch	Length of Perfect Screw
Inches	Inches	Inches	Inch	No.	Inch
⅛	0.270	0.405	0.068	27	0.19
¼	0.364	0.540	0.088	18	0.29
⅜	0.494	0.675	0.091	18	0.30
½	0.623	0.840	0.109	14	0.39
¾	0.824	1.050	0.113	14	0.40
1	1.048	1.315	0.134	11½	0.51
1¼	1.380	1.660	0.140	11½	0.54
1½	1.610	1.900	0.145	11½	0.55
2	2.067	2.375	0.154	11½	0.58
2½	2.468	2.875	0.204	8	0.89
3	3.067	3.500	0.217	8	0.95
3½	3.548	4.000	0.226	8	1.00
4	4.026	4.500	0.237	8	1.05
4½	4.508	5.000	0.246	8	1.10
5	5.045	5.563	0.259	8	1.16
6	6.065	6.625	0.280	8	1.26
7	7.023	7.625	0.301	8	1.36
8	7.982	8.625	0.322	8	1.46
9	9.000	9.688	0.344	8	1.57
10	10.019	10.750	0.366	8	1.68

TABLE No. 4

DATA SHEET

U.S. STANDARD SYSTEM

Diameter of Bolt	Threads per inch	DIMENSIONS OF BOLT HEAD AND NUT					Tap Drill	Tensile Strength at stress of 6,000 lbs. per sq. inch	Diameter at Root of Thread
		Long Diameter		Short Diameter	Depth				
		Hexagonal	Square		Nut	Head			
$\frac{1}{4}$	20	$\frac{9}{16}$	$\frac{23}{32}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	160	.185
$\frac{5}{16}$	18	$\frac{11}{16}$	$\frac{27}{32}$	$\frac{19}{32}$	$\frac{5}{16}$	$\frac{19}{64}$	$\frac{1}{4}$	270	.240
$\frac{3}{8}$	16	$\frac{25}{32}$	$\frac{31}{32}$	$\frac{11}{16}$	$\frac{3}{8}$	$\frac{11}{32}$	$\frac{5}{16}$	410	.294
$\frac{7}{16}$	14	$\frac{29}{32}$	$1\frac{3}{32}$	$\frac{25}{32}$	$\frac{7}{16}$	$\frac{25}{64}$	$\frac{23}{64}$	560	.344
$\frac{1}{2}$	13	1	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{27}{64}$	760	.400
$\frac{9}{16}$	12	$1\frac{1}{8}$	$1\frac{3}{8}$	$\frac{31}{32}$	$\frac{9}{16}$	$\frac{31}{64}$	$\frac{31}{64}$	1,000	.454
$\frac{5}{8}$	11	$1\frac{7}{32}$	$1\frac{1}{2}$	$1\frac{1}{16}$	$\frac{5}{8}$	$\frac{17}{32}$	$\frac{17}{32}$	1,210	.507
$\frac{3}{4}$	10	$1\frac{7}{16}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	1,810	.620
$\frac{7}{8}$	9	$1\frac{21}{32}$	$2\frac{1}{32}$	$1\frac{7}{16}$	$\frac{7}{8}$	$\frac{23}{32}$	$\frac{3}{4}$	2,520	.731
1	8	$1\frac{7}{8}$	$2\frac{5}{16}$	$1\frac{5}{8}$	1	$\frac{13}{16}$	$\frac{27}{32}$	3,300	.837
$1\frac{1}{8}$	7	$2\frac{3}{32}$	$2\frac{9}{16}$	$1\frac{13}{16}$	$1\frac{1}{8}$	$\frac{29}{32}$	$\frac{31}{32}$	4,160	.940
$1\frac{1}{4}$	7	$2\frac{5}{16}$	$2\frac{27}{32}$	2	$1\frac{1}{4}$	1	$1\frac{3}{32}$	5,350	1.065
$1\frac{3}{8}$	6	$2\frac{17}{32}$	$3\frac{3}{32}$	$2\frac{3}{16}$	$1\frac{3}{8}$	$1\frac{3}{32}$	$1\frac{3}{16}$	6,340	1.160
$1\frac{1}{2}$	6	$2\frac{3}{4}$	$3\frac{11}{32}$	$2\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{16}$	$1\frac{5}{16}$	7,770	1.284
$1\frac{5}{8}$	$5\frac{1}{2}$	$2\frac{31}{32}$	$3\frac{5}{8}$	$2\frac{9}{16}$	$1\frac{5}{8}$	$1\frac{9}{32}$	$1\frac{13}{32}$	9,090	1.389
$1\frac{3}{4}$	5	$3\frac{3}{16}$	$3\frac{7}{8}$	$2\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	10,470	1.491
$1\frac{7}{8}$	5	$3\frac{13}{32}$	$4\frac{5}{32}$	$2\frac{15}{16}$	$1\frac{7}{8}$	$1\frac{15}{32}$	$1\frac{5}{8}$	12,300	1.616
2	$4\frac{1}{2}$	$3\frac{19}{32}$	$4\frac{13}{32}$	$3\frac{1}{8}$	2	$1\frac{9}{16}$	$1\frac{3}{4}$	13,000	1.712
$2\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{1}{32}$	$4\frac{15}{16}$	$3\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{31}{32}$	18,100	1.962
$2\frac{1}{2}$	4	$4\frac{15}{32}$	$5\frac{15}{32}$	$3\frac{7}{8}$	$2\frac{1}{2}$	$1\frac{15}{16}$	$2\frac{3}{16}$	22,300	2.176
$2\frac{3}{4}$	4	$4\frac{29}{32}$	6	$4\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{7}{16}$	27,700	2.426
3	$3\frac{1}{2}$	$5\frac{11}{32}$	$6\frac{17}{32}$	$4\frac{5}{8}$	3	$2\frac{5}{16}$	$2\frac{5}{8}$	32,500	2.629
$3\frac{1}{4}$	$3\frac{1}{2}$	$5\frac{25}{32}$	$7\frac{1}{16}$	5	$3\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{29}{32}$	39,000	2.879
$3\frac{1}{2}$	$3\frac{1}{4}$	$6\frac{7}{32}$	$7\frac{19}{32}$	$5\frac{3}{8}$	$3\frac{1}{2}$	$2\frac{11}{16}$	$3\frac{1}{8}$	45,300	3.100
$3\frac{3}{4}$	3	$6\frac{5}{8}$	$8\frac{1}{8}$	$5\frac{3}{4}$	$3\frac{3}{4}$	$2\frac{7}{8}$	$3\frac{11}{32}$	51,800	3.317
4	3	$7\frac{1}{16}$	$8\frac{21}{32}$	$6\frac{1}{8}$	4	$3\frac{1}{16}$	$3\frac{19}{32}$	59,700	3.567
$4\frac{1}{4}$	$2\frac{7}{8}$	$7\frac{1}{2}$	$9\frac{3}{16}$	$6\frac{1}{2}$	$4\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{13}{16}$	68,000	3.798
$4\frac{1}{2}$	$2\frac{3}{4}$	$7\frac{15}{16}$	$9\frac{23}{32}$	$6\frac{7}{8}$	$4\frac{1}{2}$	$3\frac{7}{16}$	$4\frac{1}{32}$	76,500	4.028
$4\frac{3}{4}$	$2\frac{5}{8}$	$8\frac{3}{8}$	$10\frac{1}{4}$	$7\frac{1}{4}$	$4\frac{3}{4}$	$3\frac{5}{8}$	$4\frac{9}{32}$	85,500	4.255
5	$2\frac{1}{2}$	$8\frac{13}{16}$	$10\frac{25}{32}$	$7\frac{5}{8}$	5	$3\frac{13}{16}$	$4\frac{1}{2}$	94,000	4.480
$5\frac{1}{4}$	$2\frac{1}{2}$	$9\frac{1}{4}$	$11\frac{5}{16}$	8	$5\frac{1}{4}$	4	$4\frac{3}{4}$	105,500	4.730
$5\frac{1}{2}$	$2\frac{3}{8}$	$9\frac{11}{16}$	$11\frac{27}{32}$	$8\frac{3}{8}$	$5\frac{1}{2}$	$4\frac{3}{16}$	$4\frac{31}{32}$	116,000	4.953
$5\frac{3}{4}$	$2\frac{3}{8}$	$10\frac{3}{32}$	$12\frac{3}{8}$	$8\frac{3}{4}$	$5\frac{3}{4}$	$4\frac{3}{8}$	$5\frac{7}{32}$	127,000	5.203
6	$2\frac{1}{4}$	$10\frac{17}{32}$	$12\frac{29}{32}$	$9\frac{1}{8}$	6	$4\frac{9}{16}$	$5\frac{7}{16}$	138,000	5.423

TABLE No. 5

$\frac{x}{8} + \frac{1}{10}$